

APPLE'S (PROPOSED) REDACTIONS

EXHIBIT 1
[Filed Under Seal]

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
OAKLAND DIVISION

APPLE IPOD ITUNES ANTI-TRUST
LITIGATION

Lead Case No. C-05-00037-YGR

**DECLARATION OF ROGER G. NOLL
ON LIABILITY AND DAMAGES**

My name is Roger G. Noll, and I have submitted six declarations in this proceeding.¹ My declaration of January 18, 2011, contains a description of my qualifications and a list of the antitrust cases in which I submitted a declaration, was deposed, and/or testified at trial. Since that date I have published a book and several articles, and have received two awards: the Alfred E. Kahn Distinguished Career Award from the American Antitrust Institute and the Distinguished Member Award of the Transportation and Public Utilities Group of the American Economic Association. My updated curriculum vita is attached as Appendix A to this declaration.

Since January 2011, I have testified in person in the following proceedings.

SmithKlein Beecham d/b/a GlaxoSmithKline vs. Abbott Laboratories (U.S. District Court, Oakland);

Novell vs. Microsoft (U. S. District Court, Salt Lake City);

DVD CCA vs. Kaleidescape (Superior Court, San Jose); and

1. *Declaration of Roger G. Noll* (July 15, 2008), *Reply Declaration of Roger G. Noll* (October 19, 2009), *Declaration of Roger G. Noll* (January 18, 2011), *Reply Declaration of Roger G. Noll* (March 28, 2011), *Supplemental Declaration of Roger G. Noll* (July 18, 2011), and *Second Supplemental Declaration of Roger G. Noll* (September 23, 2011).

In the Matter of Adjustment of Rates and Terms for Pre-existing Subscription and Satellite Digital Audio Radio Service (Copyright Royalty Board, Washington, D. C.).

I have submitted declarations and have been deposed in the following additional cases.

Sarah Perez, et al., vs. State Farm Mutual Automobile Insurance Co., et al. (U.S. District Court, San Jose);

Federal Trade Commission vs. Cephalon (U.S. District Court, Philadelphia);

In re Text Messaging Antitrust Litigation (U.S. District Court, Chicago); and

In re NCAA Student Athlete Name and Likeness Licensing Litigation (U.S. District Court, Oakland).

I am the co-author of an *amicus* submission to the Federal Communications Commission.

Petition to Reconsider Sports Blackout Rules (Federal Communications Commission).

ASSIGNMENT

Attorneys for the class plaintiffs in this litigation have asked me to undertake an antitrust economics analysis of the liability and damages issues in this litigation. I have been asked to determine whether the update to the iTunes digital media player software, known as iTunes 7.0, caused harm to competition in a relevant market for portable digital media players and, if so, to calculate the damages to members of the class of purchasers of iPods from the date at which the update was issued on September 12, 2006, until the end of the class period, March 31, 2009.

In undertaking this assignment I have read the legal submissions by the parties and the decisions by the court in this case, the defendant's answers to interrogatories, the

expert reports submitted on behalf of the defendant in earlier phases of this litigation, numerous discovery documents and depositions, and many publications about the sound recording, consumer electronics and wireless communication industries. The discovery material that I reviewed, including the material that I reviewed for my prior reports, is listed in Appendix B. Appendix B also includes the publications on which I relied, including publications from my prior reports. I also have relied on my 45 years of experience in analyzing the economics of the communications industry. In undertaking my analysis, including the statistical analysis of the data that have been produced by the defendant, I have been assisted by the professional staff at Economists, Inc.

SUMMARY

The plaintiffs in this litigation allege that Apple maintained and enhanced its monopoly power in the market for portable digital media players by releasing iTunes 7.0, an update of the software that is used to store and catalog digital audio files on a personal computer and an iPod, and making other changes to the internal electronics of new iPods models. For convenience, I refer to all of these changes as the iTunes 7.0 update.

The class contains all entities except government agencies and Apple employees that purchased iPods directly from Apple from September 12, 2006 (the release date of iTunes 7.0) until March 31, 2009 (the day before Apple began selling downloads of audio recordings from all of the major record companies that were not protected by a digital rights management (DRM) system). Apple classifies its customers into two groups. Apple defines “resellers” as entities that purchase iPods for resale, including retail stores and wholesale distributors that sell to retail stores. Apple defines “direct purchasers” as

customers that do not buy for resale, including individual consumers, corporations, elementary and secondary schools, and government agencies. Apple also classifies university bookstores as direct purchasers.

The iTunes 7.0 update disabled Harmony, a software product from RealNetworks that allowed owners of iPods to assemble a library of audio files from the RealPlayer Music Store (RMS) that could be played on both iPods and portable digital media players that competed with iPods. The plaintiffs allege that disabling Harmony increased the cost of switching from iPods to other brands of portable digital media players and thereby harmed consumers by limiting choice and causing higher prices for iPods.

I have undertaken an antitrust economic analysis of these allegations. This section summarizes my conclusions.

First, the conduct that is alleged in the plaintiffs' complaint is an example of "lock-in," which is a form of foreclosure that arises from actions that increase the cost to consumers of switching to a product that has better quality and/or a lower price. In this case the iTunes 7.0 update raised the cost of switching from iPods to competing portable digital media players by eliminating the ability of consumers to collect a library of downloads that could be played on all players. Thus, the iTunes 7.0 update had the effect of increasing the extent of lock-in for iPod owners. This effect is important because the average replacement rate for iPods during the class period is short, about two years.

Second, although the presence of market power is not necessary for lock-in to reduce efficiency and to cause harm to competition, in this case Apple enjoyed market power during the class period in two relevant antitrust markets: the market for portable digital media players, which includes iPods, and the market for permanent downloads of

digital audio files, which includes Apple's download service, originally the iTunes Music Store but subsequently the iTunes Store (iTTS). Apple enjoyed monopoly power in both markets from the launch of iTTS in April 2003 until at least the end of the class period.

Third, Apple enhanced and maintained its monopoly power in portable digital media players by making iPods incompatible with audio files that were downloaded from sites other than iTTS. Periodic replacement of a portable digital media player is attractive to consumers because rapid technological change allows greater memory, faster and more powerful internal electronics, longer battery life, sleeker design from miniaturization, and better sound reproduction. After the iTunes 7.0 update, users of new iPods could not acquire downloads that could be played on both iPods and competing portable digital media players until iTTS and its competitors began to sell downloads that were not encrypted. As a result, consumers who bought iPods with the iTunes 7.0 update and who purchased downloads could not avoid buying from iTTS, and if they did, they would face a switching cost if they chose to replace their iPod with a competing player. This higher switching cost increased Apple's monopoly power in the market for portable digital media players.

Fourth, Apple's actions to make downloads from RMS incompatible with new iPods enabled Apple to charge higher prices for iPods than otherwise would have been the case. The damages in this case are the overcharge on iPods during the class period due to the incompatibility that was created by iTunes 7.0. Several hedonic regression models were estimated using Apple's transactions records. The preferred model is a logarithmic price equation that excludes observations with missing data or "outlier" prices. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

ECONOMIC BACKGROUND

I understand that the issues in this case have been narrowed to the competitive effects of Apple's update of iTunes 7.0. To analyze this issue requires information about how the evolution of digital distribution of audio files led to technical incompatibility between Apple's products and the products of competitors, and about how technical incompatibility caused lock-in and thereby reduced the intensity of competition. The goal of this section is to explain the causes and effects of lock-in as it applies to portable digital media players. Because lock-in can arise for reasons other than anticompetitive conduct, the discussion covers events other than the iTunes 7.0 update that affected the extent to which Apple's customers were locked in to iPods.

The History of Audio Downloads and Portable Digital Media Players

Until the 1990s sound recordings were offered to consumers only in physical formats, such as audio tapes, vinyl records, or compact discs (CDs). By the 1980s digital files could be delivered to personal computers over the telecommunications network, but the speed of network transmission was too slow to make delivery of high-quality musical

recordings practical. Eventually technological progress enabled telecommunications carriers to support the delivery of high-quality sound recordings.

By the mid 1990s the quality of telecommunications had advanced sufficiently to permit the digital distribution of music over the Internet. Beginning about 1997 several firms introduced technology to deliver digital audio files to a computer,² but the record industry was slow to embrace the technology. The first e-commerce Internet sites that sold audio files from major record labels operated as mail-order retailers, offering the opportunity to buy physical copies of recordings via the mail or other delivery services. By 2000 nearly 85 percent of retailers had launched web sites for this purpose, and Internet sites accounted for about three percent of retail sales.³

An important advantage of Internet distribution is that it eliminates the need to manufacture, store, ship and display physical products. Despite the prospect for a large cost reduction for suppliers and much greater convenience for customers, the record companies were reluctant to offer most of their catalogues for sale as downloads over the Internet. As a result Internet sites such as Napster and Grokster had an opportunity to offer illegal “file sharing” services without serious competition from legal Internet sources. By 1999, when Napster was launched, “retailers and wholesalers have been

2. “Statement by Mike Farrace,” Hearings before the Committee of the Judiciary, U.S. Senate, April 3, 2001, 2001 WL 323720 (F.D.C.H.). This testimony also is available on the web site of the National Association of Recording merchandisers, www.narm.com.

3. “2000 Annual Survey Results,” National Association of Recording Merchandisers, pp. 1, 5, and *Music and the Internet: Celestial Jukebox*, Lehman Brothers (Europe), November 9, 2000, pp. 21-24, 28, as cited in Roger G. Noll, “Napster’s Copyright Misuse Defense and the Future of Internet Distribution of Music,” an essay derived from the public version of my expert report in the Napster case.

ready, willing and able to deliver secure online entertainment...”⁴ During the period when Napster operated, legal retail sales of digital music were minuscule. In 2000 digital distribution revenues “were almost too small to measure.”⁵ Exhibit 1 shows the amount of revenue accounted for by physical copies, downloads, and digital streaming services. In 2004 downloads accounted for only about 1.3 percent of total sales.

Meanwhile, the first portable digital media player, called the MPMan F10, was brought to market in 1998, but the first player to be favorably received was the Rio PMP300 a few months later.⁶ In 2001, Apple entered the market with its first iPod, and became one of the handful of players to obtain significant sales. These early products were accompanied by software, called somewhat confusingly a digital media player, that could transfer, store, and play digital audio files from a CD on a personal computer.

During the period when digital distribution of music was dominated by illegal file-sharing sites, record companies jointly developed a business plan for downloads with two key elements. First was to protect audio files by using DRM systems, one purpose of which was to create an impediment to file sharing among consumers. Second, DRM also would allow record companies to control the distribution and uses of digital music, such as by limiting the number of times that a file could be played without further payment.

To carry out this plan the then-five major record distribution companies⁷ formed two

4. “Statement of National Association of Recording Merchandisers,” Hearings before the Committee of the Judiciary, U. S. Senate, April 3, 2001, p. 1 (www.narm.com).

5. NARM, “2000 Annual Survey Results,” *op. cit.*, p. 6.

6. Alex Cosper, “The History of the Portable MP3 Player,” *eHow*, no date, at http://www.ehow.com/about_5409458_history-portable-mp-players.html.

7. The five companies have become three: Universal/EMI, Sony/BMG, and Warner.

joint ventures, MusicNet and PressPlay, to sell rights to distribute recordings to retail download sites. BMG, EMI and Warner were partners in MusicNet, while Sony and Universal were partners in PressPlay.

The five major record companies gave MusicNet and PressPlay identical non-exclusive licenses to the same recordings. The only major difference between these sites was that they used different DRM formats (RealNetworks and Microsoft). The services shared two undesirable features: a limited selection of music and extensive restrictions on the use of downloads. Because of these limitations, an article in a leading computer trade magazine ranked them 9th on the list of the worst tech products of all time.⁸

Before consumers had time to make their own judgments about these services, the record companies were handed a major setback in their infringement litigation against Napster. The judge in that case refused to issue a permanent injunction against Napster until the court decided whether the record companies' involvement in MusicNet and PressPlay was anticompetitive and so constituted copyright misuse.⁹ Within a few months the record companies divested these joint ventures.

Approximately one year after the Napster decision, Apple launched iTunes in April 2003. The important breakthroughs for iTunes were a much larger inventory of audio files than were available on previous download sites and some relief from limitations on the use of downloads. Other sites with these characteristics were not authorized until six months later. One limitation on iTunes and its competitors was the requirement from record

8. Dan Tyson, "The 25 Worst Tech Products of All Time," *PC World*, May 26, 2006, at www.pcworld.com/article/125772-3/the_25_worst_tech_products_of_all_time.html.

9. "Memorandum and Order," *In re Napster, Inc., Copyright Litigation*, U.S. District Court (Northern California), Case No. MDL 00-1369 MHP, February 2002.

companies to use DRM protection. From its launch until the end of the class period the downloads for sale on iTS from four of the five major record companies were protected by Apple's proprietary DRM system, FairPlay.¹⁰

FairPlay and other DRM systems for downloads can be circumvented legally, but the process is cumbersome and costly. Media player software allows computers to burn CDs from downloaded audio files, although there are limits to the number of times each sound recording can be burned. Files that are burned to a CD are not DRM-protected, so a consumer can convert a DRM-protected file to an unprotected file by burning the CD and then reloading it on the computer. Because converting protected files to unprotected files is costly and time consuming, customers who purchased downloads became locked in to the particular DRM system that was compatible with their portable digital media player. Because Apple chose not to license FairPlay¹¹ and not to permit downloads from other Internet sites to play on an iPod, Apple's customers also were locked in to both iTS for downloads and iPods for players.¹²

10. EMI abandoned DRM protection for recordings sold by iTS in April 2007. The other labels did not allow iTS to sell recordings in an unprotected format until 2009.

11. Before Apple introduced the iPhone, Motorola was licensed to manufacture a feature phone that included a portable digital media player and that could access iTS, but this license was not renewed after Apple introduced the iPhone. Matthew Hicks, "Motorola Previews iTunes Phone," January 7, 2005, *eWeek.com*. See also AIIA00328028-29 (Apple internal email regarding Motorola's official press announcement). Hewlett-Packard apparently is the only equipment manufacturer to have an agreement with Apple to market an iPod with the HP brand. These devices also were capable of playing audio files in the FairPlay format.

12. For analysis that reaches similar conclusions about the effects of FairPlay and other DRM systems on consumer welfare, see Neil Weinstock Netanel, "Temptations of the Walled Garden: Digital Rights Management and Mobile Phone Carriers," *Journal on Telecommunications and High-Technology Law* Vol 6 (2007-08), pp. 77-100, and Thierry Reyna and Ludmila Striukova, "White Knight or Trojan Horse? The

From the launch of iTunes through the end of the class period, the most important competing proprietary DRM formats were Microsoft's Windows Media Audio (WMA) and RealAudio from RealNetworks. Both were licensed to others and were compatible with many portable digital media players, although Microsoft also had a proprietary version of WMA that was used only in connection with its portable digital media player, Zune (discontinued in October 2011¹³). Thus, neither WMA (except the Zune version) nor RealAudio caused their customers to be locked in to one brand of portable media player, although both created switching costs for consumers who use a portable media player that supports one DRM system (say, RealAudio) but who would like to switch to a player that supports the other DRM system (say, WMA). Because many players support each DRM system, the lock-in effect of these systems reduces competition only among download sites, not among portable media players.

The software that enables consumers to load and play digital audio files is called, somewhat confusingly, a digital media player (not to be confused with portable digital media player, which is a physical device for playing digital audio files). A digital media player allows a consumer to transfer, store, catalog and play audio and video files on a personal computer, to burn those files on a CD if permitted by the DRM system, and to transfer and catalog these files to a portable digital media player. Apple's iTunes is the only digital media player that can download and play a recording in the FairPlay format. Recordings in the FairPlay format can not be transferred to and played on any portable digital media player other than an iPod without using another program and, in almost all

Consequences of Digital Rights Management for Consumers, Firms and Society," *Communications & Strategies* No. 69 (1st Quarter, 2008), pp. 109-26.

13. Owen Williams, "Zune Player Officially Discontinued," *Simcity*, October 4, 2011, at <http://www.neowin.net/news/zune-player-officially-discontinued>.

cases, a CD burner or other electronic equipment.¹⁴ Likewise, iTunes can not convert WMA or RealAudio DRM-protected files into a format that can be played by an iPod. During the class period audio files in each of the latter two formats could be played on several brands of portable digital media players. Thus, iTunes played an essential role in maintaining technical incompatibility between the defendant's products and competing products in the relevant markets.

Several other formats that have no DRM protection have been available since before the launch of iTunes and can be played on iPods. The most important DRM-free formats are AAC and MP3. While iPods are not compatible with RealAudio and WMA, they can play audio files in unprotected MP3 and AAC formats.¹⁵ By January 2008, the major record companies all had agreed to let Internet vendors other than iTunes sell downloads in unprotected formats. After that date iPod owners could buy downloads from sites other than iTunes and use iTunes to load these files on an iPod. In January 2009 Apple announced that iTunes would sell audio files in the unprotected AAC format. By April 1, 2009, iTunes's transition to DRM-free files was complete. Since that time nearly all new downloads could be played on any portable digital media player so that all first time buyers of portable digital media players were free of lock-in arising from a proprietary audio file format; however, owners of older iPods who had substantially libraries of DRM-protected audio files remained locked in when they replaced their old player.

The events that culminated in the iTunes 7.0 update began in July 2004 when

14. Some hackers have offered programs for breaking FairPlay's encryption and converting a protected file from iTunes to an unprotected AAC or MP3 file, but these programs are not wholly successful and in at least some cases may be illegal.

15. For more details about which audio formats are compatible with an iPod, see Apple's web site: <http://support.apple.com/kb/HT1334>.

RealNetworks released RealPlayer 10.5, an upgrade of RealNetwork's counterpart to Apple's iTunes media player software. This upgrade included Harmony, a software product that allowed users to play a download from RMS on an iPod. In August, RealNetworks announced its "Freedom of Choice" campaign to promote Harmony, offering records at half price (49 cents per song and \$4.99 per CD) on RMS.¹⁶

As discussed in the report by plaintiffs' technical expert, Dr. David Martin, that was submitted with plaintiffs' opposition to defendant's motion for summary judgment, in October 2004 Apple issued iTunes 4.7, an iTunes update that restored incompatibility between new iPods and files that were downloaded from RMS. This update prevented consumers from playing RMS downloads on new iPod models and made old downloads from RMS that were compatible with a customer's old iPod incompatible with a new iPod. An iPod owner who had taken advantage of the RealNetworks 50 percent off sale to buy downloads from RMS could not play these files on a new iPod.

In April 2005 RealNetworks responded to iTunes 4.7 by releasing an upgrade of Harmony that restored compatibility between iPods and audio files from RMS. This upgrade worked for about a year and a half. According to Dr. Martin, the iTunes 7.0 update, including firmware on new iPod models that were released after September 12, 2006, created a new form of incompatibility between iPods and audio files that had been downloaded from RMS. RealNetworks never overcame this new incompatibility. As a result, new iPod owners who wanted to download audio files that were protected by a digital rights management system were forced to acquire these recordings from iTS, and

16. The RealNetworks press release, dated August 17, 2004, is available on PRNewswire at <http://www.prnewswire.com/news-releases/realnetworks-kicks-off-freedom-of-choice-campaign-with-biggest-music-sale-in-history-71643667.html>.

in so doing continue to build a library that locked them into iPods.

The Economics of Lock-In

The incompatibility between some iPods and downloads from RMS had two effects on owners of these iPods. First, these iPods could not play DRM-protected audio files from RMS, forcing customers to use iTunes to obtain downloads. Second, owners of iPods who had used RMS and thereby had lower switching costs, by being forced to use iTunes for downloads, began building a library of files that increased the cost of switching to a competing player. An iPod owner who purchased downloads from iTunes and who contemplated switching to a competing player faced a choice of three costly alternatives: (1) abandon playing files obtained from iTunes on the new player; (2) burn iTunes audio files onto CDs and upload them to a computer for the purpose of loading them onto the new player; or (3) repurchase the audio files obtained from iTunes in a DRM format that was compatible with the new player. Each option imposes a switching cost.

Another consequence of the incompatibility between iPods and downloads from RMS involves a network effect. A network effect occurs when the value of a product is greater if other people buy the same product. Because a download can be played on several portable digital media players, members of the same family can share downloads if the audio files are compatible with the iPods. Suppose a music customer, Person A, has not bought any audio files from iTunes, does not want to play any recordings that family members have acquired from iTunes, and so does not face a cost to switch to a competing player. But if other family members would like to play audio files that are downloaded by Person A, they will suffer a loss if Person A starts downloading files from RMS.

Switching costs and network effects cause “lock-in,”¹⁷ which occurs when a customer incurs a cost by changing brands. Lock-in does not imply that customers cannot change brands. Instead it refers to a circumstance in which a customer has an incentive not to change brands. Lock-in allows a brand profitably to set prices above the competitive level. For simplicity, call the brand that a customer currently owns the incumbent and call the alternative brand the challenger. Assume that a consumer’s old portable media player is worn out or obsolete. Also assume that the incumbent’s price is P_i , the challenger’s price is the competitive market price P_c , the switching cost is S , and the value of the network effect benefit of the incumbent is N . If the incumbent and the challenger are otherwise identical in function and quality (i.e., except for switching costs and network effects the products are perfect substitutes), the incumbent can retain the customer if $P_i < P_c + S + M$. Thus, the incumbent has market power in that it profitably can set price above the competitive level. If customers of all brands are locked in, the same argument holds for each brand, and all prices will be above the competitive level.

One inference to be drawn from the preceding analysis is that lock-in is not an either/or condition. Specifically, a change in switching costs, S , causes an equal change in the maximum price, P_i , that the incumbent can charge. Thus, small changes in S have small effects on P_i . If a product has numerous sources of lock-in, including a strong brand-name reputation, the elimination of another source of lock-in, such as technical

17. On the economics of lock-in, see Carl Shapiro and Hal Varian, *Information Rules: A Strategic Guide to the Information Economy*, Harvard University Press, 1999; Pei-yu Chen and Lorin M. Hitt, “Information Technology and Switching Costs,” in Terrence Hendershott, *Handbook on Economics and Information Systems*, Elsevier, 2006, pp. 437-70; Joseph Farrell and Paul Klemperer, “Coordination and Lock-in: Competition with Switching Costs and Network Effects,” in Mark Armstrong and Robert Porter, *Handbook of Industrial Organization* Vol. 3, Elsevier, 2007, pp. 1967-2072.

incompatibility, will not cause P_i to fall to P_c .

An important characteristic of lock-in is that even if markets otherwise are competitive, lock-in still can cause higher prices.¹⁸ Suppose that in the beginning no customers have made a purchase so no customers are locked in to any brand. If suppliers know that new customers will be locked in after purchase, and if they cannot negotiate in the first period the prices that will be charged in future periods because important factors that influence price, such as technological change and input prices, are not predictable, then both customers and suppliers know that repurchase prices will exceed the competitive level. In this circumstance, suppliers will compete for customers by offering initial prices that are below the competitive level. The magnitude of the initial price cuts and the subsequent overcharges will be determined by the fraction of future purchases that are accounted for by new customers.

The preceding example of lock-in in competitive markets may seem to leave both consumers and suppliers unharmed because the monopoly profits in later period are offset by price cuts in the initial period. While suppliers are not harmed by this circumstance, consumers usually are, although there are exceptions. In most cases the product in question does not operate perfectly up to a date at which it ceases to function and so must be replaced. Instead, the performance gap between new and old products tends gradually to increase over time. In this case a consumer will purchase a new product when the value of the performance differential becomes greater than the net price (the gross price

18. This paragraph summarizes the analysis in Severin Borenstein, Jeffrey K. Mackie-Mason, and Janice S. Netz, "Antitrust Policy in Aftermarkets," *Antitrust Law Journal* Vol. 63 (1994-95), pp. 455-82. This analysis was applied in *Eastman Kodak v. Image Technical Services*, 112 S. Ct. 2072 (1992). The competitive first purchase was a high-speed photocopier and the monopolized subsequent purchases were repair services.

minus any trade-in or resale value) of buying a new product. If products are sold at the competitive price in all periods, consumers will replace old products more frequently than if the price of new products in later period exceeds the competitive price. The delay in replacement from the date at which it is efficient (determined by the competitive price) to a later date (determined by the monopoly price) harms consumers.

Lock-in can lead to higher prices even if not all customers are locked in. Lock-in causes demand in later periods to be less elastic (i.e., less responsive to changes in price). A seller that could distinguish between buyers according to whether they are locked in would be able profitably to increase price to the locked in customer while retaining the same price and profitability on sales to customers who were not locked in. But a seller that cannot make this distinction will perceive that the overall demand for the product has become less elastic. The new elasticity will be a weighted average of the elasticities of the locked in and not locked in customers.¹⁹

Whether lock-in harms consumers is an empirical issue. The previous examples are based on a market in which all consumers buy a product in the first period, with no

19. For example, suppose the market initially has 100 customers, each of whom has a demand, Q , for the product given by $Q = 10 - P$, where P is the price. For ease of exposition, assume that the product is costless to produce, so that the supplier maximizes total revenue $R = 100(10 - P)P = 1000P - 100P^2$. In this case the profit-maximizing price is 5 and the supplier sells 500 units, five to each customer, for a total profit of 2500. Suppose that 20 of these customers become locked in, meaning that their replacement demand is less elastic. Thus, in the period in which the product is replaced, 80 customers have the old demand but 20 customers have a new, less elastic demand, given by $Q = 7 - .4P$. Note that at the old price, 5, each of these customers would still buy 5 units. Thus, the demand faced by the supplier in the replacement period is $80(10 - P) + 20(7 - .4P) = 940 - 88P$. Revenue is now $(940 - 88P)P$, the profit-maximizing price is 5.34, the quantity sold is 475, and profit has increased to 2536.50. The harm to consumers has two components: the 34 cent price increase (a total cost of 36.50) and a loss of 25 units of the product, which had a net value to consumers of $\frac{1}{2}(.34)(25) = 4.25$ (the familiar dead-weight loss of monopoly).

new customers arriving in the next period when the first customers are locked in, and in which there are no economies of scale that cause the incremental cost of production to fall as production is increased. In a market that is growing rapidly and in which costs fall as production increases, a supplier is especially interested in attracting new customers, so that prices in later periods may be determined primarily by the desire to attract them. Thus, lock-in normally has a greater effect on price as the fraction of sales that are accounted for by replacement purchases grows.

The economics of lock-in applies to digital audio files and portable digital media players. A download is a highly durable asset that can be used without degradation in quality for an indefinitely long period. A digital audio file loses economic value to a consumer only if the consumer no longer wants to listen to it.

A portable media player has a shorter economic life, in part because the products can be lost, stolen or broken, and in part due to rapid technological progress in microelectronics. The electronics in portable media players are semiconductor products that follow Moore's Law, first enunciated by Intel co-founder Gordon Moore. According to Moore's Law, the amount of functionality that can be placed on a semiconductor of a given size doubles every 18 months. For portable media players, Moore's Law is the source of larger memory, better sound quality, miniaturization, and the addition of video. These factors cause the ownership life cycle (average replacement rate) of portable digital media players and cell phones to be between 18 and 24 months.²⁰

20. Jemima Kiss, "How Big Is the iPod Installed Base?" *Guardian*, September 9, 2009 (reporting discussion with executive at Forrester Research); Larry Dignan, "Tablet Replacement Rates: More Like an MP3 Player than PC," *ZDNet* January 4, 2011 (reporting a Forrester Research study); "Mobile Phone Lifecycles," GSM Association, 2006 (reporting that about half of phone sales are replacements and that the replacement

The economics of lock-in in the information technology sector of the economy has been extensively studied. Several studies examine the effects of changes in telecommunications policies that reduce switching costs and network effects.

One example is the introduction of “number portability,” which allows phone customers who change carriers to keep their old telephone numbers. In the absence of number portability customers who switch carriers must go to the trouble and expense of notifying those with whom they communicate that their numbers have changed. Number portability eliminates this switching cost. Scholars have quantified switching costs by studying the effect of adopting number portability on prices, churn (the rate at which customers switch carriers), and the market share of the dominant carrier. These studies find that number portability increases churn, lowers the market share of the dominant carrier, and reduces prices, from which they conclude that this reduction in switching costs intensified competition among carriers.²¹

rate is about 18 months); “The Life Cycle of a Cell Phone,” U.S. Environmental Protection Agency, 2005 (reporting cell phone replacement rate of 18 months); John Paczkowski, “I Got a Fever, and the Only Prescription is... More iPhone!” *All Things Digital*, June 25, 1010 (reporting that the replacement cycle for iPhones is 14.7 months); Victor H., “Americans Replace Their Cell Phones Every 2 Years, Finns – Every Six, a Study Claims,” *Phonearena.com*, July 11, 2011 (reporting a study by Recon Analytics finding that the replacement rate for mobile phones was 18.7 months in 2007, 19.6 in 2008, and 21.1 in 2009).

21. See V. Brian Viard, “Do Switching Costs Make Markets More or Less Competitive? The Case of 800-Number Portability,” *Rand Journal of Economics* Vol. 18, No. 1 (Spring 2007), pp. 146-63 (finding U.S. toll-free service prices fell after number portability was adopted); Jung Eun Ku, Sang Woo Lee, and Tschanghee Hyun, “Value of Number Portability on Internet Phones,” *ETRI Journal* Vol. 32, No. 1 (February 2010), pp. 469-71 (finding that number portability for mobile phones that can access the Internet increased consumer welfare \$1.50 per month per user and doubled use in two months); Tokio Otsuka and Hitoshi Mitomo, “User Benefits and Operator Costs of Mobile Number Portability in Japan and Impact on Market Competitiveness,” *Telecommunications Policy* (in press), at <http://www.sciencedirect.com/science/journal/aip/03085961> (finding that mobile number portability reduced prices and the market share of the leading carrier).

Another example is the effect of unlocking mobile devices. The two principal technologies for mobile telephones are CDMA and GSM. CDMA telephones are “locked” in the sense that a phone can access the telecommunications network through only one carrier. Thus, a subscriber to a CDMA network (such as Verizon or Sprint in the U.S.) must buy a new telephone to switch to another carrier, thereby creating a lock-in to the customer’s original carrier. GSM telephones are not necessarily tied to one carrier. GSM telephones include a Subscriber Identification Module on a removable card (SIM card) that enables a customer to use the phone to connect through a specific carrier. A customer can switch carriers by changing the SIM card unless the carrier has placed a lock on the mobile device. In the U.S. a GSM customer must obtain the consent of the carrier (AT&T or T-Mobile) to unlock a phone and replace the SIM card. GSM is more commonly used than CDMA in the rest of the world and is used exclusively in the European Union. In many countries, including the European Union, GSM carriers are prohibited from locking phones, so customers can access the network through multiple carriers by simply replacing the SIM card. Research on the effect of unlocking mobile telephones concludes that prices are lower in nations in which phones are not locked.²²

These studies reference other research on the same topic.

22. Akohiro Nakamura, “Estimating Switching Costs Involved in Changing Mobile Phone Carriers in Japan: Evaluation of Lock-in Factors Related to Japan’s SIM Card Locks,” *Telecommunications Policy* 34 (2020), pp. 736-46 (finding from surveys that eliminating locked mobile phones would benefit at least 20 percent of customers and that unlocking combined with eliminating incompatibilities in content that is available on each carrier would cause a substantial increase in consumer welfare); Lucio Fuentelsaz, Juan Pablo Maicas, and Yolando Polo, “Switching Costs, Network Effects, and Competition in the European Mobile Telecommunications Industry,” *Information Systems Research* Vol. 23, No. 1 (March 2012), pp. 93-108 (finding that the nations in Europe that have the lowest prices have the lowest switching costs from the combined effects of number portability and phone unlocking, and that this effect is intensified in nations in which carrier network effects are greater). These studies also reference other

Lock-in also arises from network effects in communications when prices (whether voice or data) depend on whether customers connect through the same carrier or different carriers. Communication requires terminating the connection to the called party. Most nations use “calling party pays,” in which the carrier of the customer who initiates communication pays a termination fee to the terminating carrier. A carrier then passes on the termination fee to the customer who originates the communication. Carriers compete for customers over the price of originating a connection, but a carrier has a monopoly on terminations to its own customers, which leads to a monopoly termination price if other policies do not prevent it. Carriers also compete by offering lower termination charges for communications that originate and terminate on the carrier’s network. This practice creates a network effect: customers who frequently communicate pay less if they all buy service from the same carrier. This network effect causes lock-in among customers who buy service from the same carrier. The policies that can be used to overcome this lock-in effect are: (1) regulate the price of termination, or (2) adopt “bill and keep,” in which carriers (and customers) are not charged for termination on other networks. Research has shown that “bill and keep,” by eliminating the monopoly in termination and the lock-in effect of affinity groups to a particular carrier, causes the lowest prices.²³

As a theoretical matter, lock-in does not necessarily harm the competitive process. Nevertheless, theoretical and empirical research concludes that the common result is that lock-in makes competition less intense and harms consumers. Professors Farrell and

research on the same issues.

23. See Fuentelsaz, et al., *op. cit.* and Stephen C. Littlechild, “Mobile Termination Charges: Calling Party Pays Versus Receiving Party Pays,” *Telecommunications Policy* Vol. 30 (2006), pp. 242-77; David Harbord and Marco Pagnozzi, “Network-Based Price Discrimination and ‘Bill-and-Keep’ vs. ‘Cost-Based’ Regulation of Mobile Termination Rates,” *Journal of Network Economics* Vol. 9, No. 1 (March 2010), pp. 1-46.

Klemperer conclude that “switching costs seem more likely to lower than to raise efficiency, so when firms favor switching costs the reason often is because they enhance monopoly or oligopoly power by directly raising prices or by inhibiting new entry.”²⁴

MARKET DEFINITION AND MARKET POWER

The plaintiffs allege that Apple enjoys monopoly power in the markets for digital audio files and portable digital media players. From the perspective of the economics of switching costs, the plaintiffs have alleged more than is required for lock-in to have an anticompetitive effect. In lock-in markets in which firms compete intensely for the first purchase, firms can enjoy *ex post* monopoly profits even if the market appears to be structurally competitive. The best outcome for consumers in this type of market is that competition in initial purchases is so intense that firms compete away their *ex post* monopoly profits by setting initial prices far below costs – a circumstance that is called a “bargain-then-ripoff pattern of prices.”²⁵ While this outcome leaves firms no better off than had switching costs not been present, it harms consumers through its effects on delaying or reducing purchases at ripoff prices.

Notwithstanding this caveat, the facts about the markets for digital audio files and portable digital media players support the plaintiffs’ allegations. This section identifies the markets in which iTunes audio files and iPod portable digital media players are sold, and then examines whether Apple enjoys monopoly power in these markets.

24. Farrell and Klemperer, *op. cit.*, p. 2006.

25. *Ibid.*

Market Definition

The purpose of relevant market analysis is to identify products that are close substitutes. In antitrust economics, a relevant market consists of a reference product (the product that is the subject of the complaint) and any close substitutes for that product that could be profitably monopolized if all products were offered by the same seller. Products are substitutes on the demand side if buyers would switch from one product to another in response to a small reduction in the relative price of the latter. Products are substitutes on the supply side if sellers would switch production from another product to a product that is a close substitute in response to a small increase in the relative price of the latter.

The task of market definition is to identify the closest substitutes for a reference product. To be close substitutes, products must be sufficiently similar that consumers regard them as substitutes for performing the same functions, and must be conveniently available to purchase them in the same geographic area. The relevant market consists of the smallest number of products that, if sold by a single supplier, would be able to impose a small but significant non-transitory increase in price (SSNIP) in comparison with the prices that are charged when each product is sold separately.²⁶

Economists use several methods to identify a relevant market. In some cases, economists estimate the cross-elasticity of demand (that is, how the sales of one product are affected by the price of another product) between the reference product and each other product that might be regarded as close substitutes. In most cases data limitations preclude econometric estimation of cross-elasticity of demand. Econometric estimation of cross-elasticities of demand is usually impossible for products that have extensive

26. *Horizontal Merger Guidelines*, U. S. Department of Justice and Federal Trade Commission, 2010 (henceforth *Merger Guidelines*).

product differentiation and that are rapidly evolving, as was the case of portable digital media players during the class period.

If reliable estimation of cross-elasticity of demand is not feasible, economists look for indirect evidence that products are close substitutes:²⁷ similarity of components and functional uses, statements outside the context of litigation by executives and industry analysts about their beliefs about which products are close competitors, and surveys of buyers about which products they considered before buying a product that is a candidate to be included in a relevant market.

The plaintiffs allege two relevant markets: downloads of digital audio files and portable digital media players. The geographic area for these markets is the United States. The reference products are iPods and iTunes as a seller of downloads of digital audio files. To define the relevant markets that include iTunes or iPods involves collecting information about prices, product characteristics, and informed beliefs among buyers, sellers and industry observers about the closest substitutes for each reference product and plausible close substitutes.

Two other products enter the analysis of competition in these product markets. These are digital media players and the formats for DRM systems for digital audio files. The analysis of competitive conditions in the markets for digital audio files and portable digital media players is affected by these products, but does not hinge on the formal definition of the product market for either of them.

27. The sources of evidence that are used in market definition, including internal records of firms and their buyers as well as reports by industry analysts, are discussed more completely in the *Merger Guidelines*, pp. 4-6, 10-11.

Portable Digital Media Players

The alleged anticompetitive conduct in this litigation involves technical features of iPods, iTunes, and iTunes that reduce the substitutability between iPods and other portable digital media players. In the retail market that includes iPods, final consumers can choose among portable digital media players. The possibility for substitution by final consumers provides an opportunity for retailers other than Apple's own retail outlets to engage in substitution in the reseller market. Hence, the appropriate focus for defining the relevant market for portable digital media players for both types of class members is to identify close substitutes for iPods among final consumers, regardless of whether Apple sold the product to a direct purchaser or a reseller.

The key characteristic of portable digital media players is the ability to play a large number of digital audio files on a compact mobile device. The technology of portable digital players has evolved since Apple introduced its first iPod in 2001. Rapid technological progress in microprocessors, memory devices, batteries, and wireless communications has been used to make players smaller and lighter, to increase the storage capacity of players, and to expand the functionality of players. In 2005 Apple introduced an iPod that could play digital video files and began to sell video downloads through iTunes.²⁸ In 2007 Apple introduced the iPod touch, which can access iTunes over the Internet and can be used for other applications, including video games.²⁹

The most obvious close substitutes for an iPod are other portable digital media

28. "Apple Unveils the New iPod" and "Apple Announces iTunes 6 with 2,000 Music Videos, Pixar Short Films & Hit Shows," Apple Press Releases, October 12, 2005. See also http://www.apple-history.com/?page=gallery&model=ipod_video.

29. "Apple Unveils the iTunes WiFi Music Store" and "Apple Unveils iPod Touch," Apple Press Releases, September 5, 2007.

players.³⁰ As of January 2011, Amazon.com offered the following brands of portable digital media players: Archos, Coby, Cowon, Creative, Ematic, Ibiza, iPods, iRiver, Latte, Meizu, Philips, Pyrus, SanDisk, Samsung, Sony, Toshiba and Zune.³¹ In 2007, CNet, a leading on-line source for reviews of consumer electronics, reviewed the following portable digital media players: Altec Lansing, Apple, Archos, Coby, Creative Zen, Cowon, iRiver, Microsoft, Philips, Samsung, San Disk, Shure and Sony.³² [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED].³³ [REDACTED]

[REDACTED]

30. For an example of detailed comparisons of the iPod and its leading substitutes, see “Portable Digital Players: iPods Rule but Consider Other Brands,” *Consumer Reports*, November 2006, at http://www.consumerreports.org/cro/electronics-computers/audio-video/audio/ipods-mp3-players/mp3-players-11-06/overview/1106_mp3_ov_1.htm.

31. In January 2011 Amazon posted lists of portable digital media players that it sold at http://www.amazon.com/MP3-Players-Audio-Video/b/ref=amb_link_86347991_3?ie=UTF8&node=172630&pf_rd_m=ATVPDKIKX0DER&pf_rd_s=top-1&pf_rd_r=0TT5Q01MYZKSP88YNK53&pf_rd_t=301&pf_rd_p=157251702&pf_rd_i=mp3; http://www.amazon.com/gp/search/ref=sr_tc_2_1?rh=n%3A1264866011%2Ck%3Amp3&keywords=mp3&ie=UTF8&qid=1294860099&sr=1-2-tc; and http://www.amazon.com/MP3-Players-Portable-Audio-Video/b/ref=amb_link_157669822_24?ie=UTF8&node=1264866011&pf_rd_m=ATVPDKIKX0DER&pf_rd_s=center-5&pf_rd_r=1T562SPGE1105HXYHVFZ&pf_rd_t=101&pf_rd_p=945911022&pf_rd_i=172630.

32. Jasmine France, “MP3 Players That Shaped 2007,” *CNet*, February 8, 2008, at http://reviews.cnet.com/4321-6490_7-6606044.html lists the five best MP3 players for 2007, from Sony, Apple, Archos, SanDisk and Creative Zen. The others can be found by searching the product manufacturers on the CNet site.

33. *Defendant Apple Inc.’s First Amended Objections and Answers to Plaintiff’s Second Set of Interrogatories 9-13*, p. 5. Rio exited the market in 2005 and so was not available during the class period.

[REDACTED]

[REDACTED]

[REDACTED]

In 2005 cell phones “transitioned from relatively simple voice and text messaging devices to gizmos capable of nearly everything a PDA can do, including instant messaging (typically on AOL or Yahoo's IM services), playing music (primarily MP3 and AAC files), displaying snippets of TV shows, capturing 1-megapixel photos, and running complex games.”³⁴ Cell phones that are bundled with portable digital media player plausibly could be substitutes for a stand-alone player.³⁵ The first music phones suffered from relatively low sound quality, slow download speeds from a PC to the player, limited storage capacity, and limited battery life when used to download and then to play audio files.³⁶ While performance improved over the next two years, the

34. Grace Acquino, “Dialed in: Best Cell Phones of 2005,” *PC World*, December 29, 2005, at <http://www.pcworld.com/article/123742/article.html>.

35 Because the price of a feature phone and, later, a smart phone is roughly equal to the sum of the prices of a digital media player and a mobile telephone, these products are an alternative to separate purchases of each device. Today mobile telephone penetration in the United States is over 275 million, so that a very large fraction of consumers who want a portable digital audio player also are likely to want a mobile telephone.

36. Thomas J. Fitzgerald, “Music to Your Cell Phone,” *New York Times*, July 7, 2005, at http://www.nytimes.com/2005/07/07/technology/circuits/07basics.html?_r=0. The Motorola Rokr, introduced in September 2005, was the first smart phone that could access iTS, but Motorola’s iTS compatible cell phone was sold for only a few months. See “The Music Cell Phone,” in *History of Mobile Phones*, Sutliffian Press, 2007, <http://www.xtimeline.com/evt/view.aspx?id=26731>. A synopsis of a review of the LG Fusic in 2006, while favorable concerning style and ease of use, stated that “the Fusic is geared more toward the occasional listener than the audiophile.” Stan Horaczek, “LG Fusic Music Phone Reviewed,” July 8, 2006, at <http://www.engadget.com/2006/07/08/lg-fusic-music-phone-reviewed/>.

performance shortfalls remained and the response was not enthusiastic.³⁷

In 2007 Apple introduced the iPhone, a “smart phone” that could access the Internet and also included the features of an iPod.³⁸ Since the summer of 2007 the closest functional substitutes for a portable digital media player is a smart phone that includes the functionality of a portable digital media player.³⁹ In 2008 some financial analysts concluded that iPhones and iPods were substitutes.⁴⁰ But during the class period the functionality of smart phones fell short of the functionality of iPods. The main

37. A review of the LG Chocolate, offered by Verizon Wireless, observed that “U.S. wireless operators have recently started shipping devices that download and play music to increase revenue from their data services, which are still primarily used for text messaging... Analysts, however, say it’ll be awhile before carriers can offer a device that would pose a strong challenge to the iPod.” Antone Gonsolves, “Verizon Launches iPod Like Music Phone,” *Information Week*, July 31, 2006, at <http://www.informationweek.com/verizon-wireless-launches-ipod-like-musi/191600770>. An article about the anticipated release of the iPhone stated that “more than half of Americans with music-capable phones also carry MP3 players” and that consumers “complain that existing music phones make it difficult to synchronize their music collections and download music...” Olga Kharif, “Another Music Phone? Yawn...” *Bloomberg-Business Week*, October 18, 2006, at <http://www.businessweek.com/stories/2006-10-18/another-music-phone-yawn-businessweek-business-news-stock-market-and-financial-advice>. For a similar assessment, see Yuki Noguchi, “Another Shot at a Music Phone,” *Washington Post*, November 7, 2006, at http://voices.washingtonpost.com/posttech/2006/11/xm_satellite_on_your_phone.html.

38. See “iPhone Premieres This Friday Night at Apple Retail Stores,” Apple press release, June 28, 2007.

39. An example of an analyst’s report that reached this conclusion is Charlie Wolf, “AAPL: Its MacWorld and We’re Just Living in It, Upgrading Apple from Buy to Strong Buy,” Needham and Company, January 23, 2008.

40. “AAPL: The Reason for the iPhone’s Reported Woes Is Closer than You Think: It’s the iPod touch,” Needham & Company, January 28, 2008, and “Apple’s Negative Guidance Tone at the FQ1 Call Means a Lower Valuation of Multiple: Hold,” Kintisheff Research, January 23, 2008. The former focuses on iPods cannibalizing the sale of iPhones, and the latter focuses on iPhones cannibalizing iPod sales.

shortfalls were storage capacity, size, and battery life.⁴¹

Although the Apple iPhone received great attention as a breakthrough in smart phones, the big jump in smart phone sales and use occurred after the end of the class period. The ability of cell phones to substitute for portable digital media players is an element of the usability of cell phones for data services. The annual reports on the wireless industry by the Federal Communications Commission (FCC) contain data about the penetration of high-speed data services over wireless devices.

The 2011 FCC wireless report covers the period during and immediately after the class period.⁴² The number of mobile telephone users who subscribed to Internet access service was 26.5 million (out of 261 million mobile subscribers) in December 2008, compared to 86 million who had devices that were capable of receiving communications at 200 kilobits per second (the FCC's threshold for defining high-speed access, which also is the necessary speed for receiving high quality streaming music services). Data were not collected on smart phones in use until after the end of the class period, but as of June 2009 the number was 40.7 million. The fraction of adults who report ever having used a mobile device for Internet access was 19 percent in December 2007 and 25 percent in April 2009. By comparison, the fraction of adults who reported owning a portable digital media player was 47 percent, and the fraction of young adults (19-34)

41. Michael Kwan, "Feature: Why Standalone MP3 Players Still Exist," *Mobile Magazine* September 17, 2008, at <http://www.mobilemag.com/2008/09/17/feature-why-standalone-mp3-players-still-exist/>.

42. Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, June 24, 2011, pp. 8-10, 95-102. The data series in this report end sometime between December 2009 and June 2010.

was 74 percent, in 2010.⁴³

Both sales of smart phones and the use of smart phones for data services grew spectacularly in the two years after the class period came to an end. The next FCC “annual report” on wireless was released in 2013, and it documents the explosive growth in the use of wireless devices for data services.⁴⁴ While total mobile telephone subscribers grew modestly to 285 million by December 2010 and 298 million in December 2011, the number of subscribers who had devices that were capable of receiving high-speed data services rose to 115.7 million in December 2009, 151.6 million in December 2010, and 183.7 million in December 2011. Of these, the number who obtained high-speed Internet access rose to 56.3 million in December 2009, 97.5 million in December 2010 and 142.1 million by the end of 2011. Thus, the number of mobile phone subscribers who even had the capability of downloading audio files to their cell phone increased nearly fivefold since the end of the class period. Between December 2007 and December 2011, data use on mobile devices increased 73 fold. In 2010, most mobile users expected that their mobile phone would replace their portable digital audio player by 2015, but by 2011 34 percent reported that this replacement had occurred.⁴⁵

The preceding data indicate that, indeed, smart phones are now competitive substitutes for portable digital media players; however, the extent to which they are close

43. Kathryn Zucker, *Generations and Their Gadgets*, Pew Internet and American Life Project, February 3, 2011, at <http://www.pewinternet.org/Reports/2011/Generations-and-gadgets/Overview.aspx>.

44. Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, March 21, 2013, pp. 9-11, 155-75.

45. *Opportunity Calling: The Future of Mobile Communications – Take Two*, Oracle Communications, October 31, 2011, p. 6.

substitutes was only just beginning at the end of the class period. Exhibit 8 shows the relationship between sales of iPods and other portable digital media players and sales of iPhones. The sale of iPhones in 2007 and 2008 were tiny compared to the sales of iPods. In 2009, sales of portable digital media players started to decline, and in late 2010 iPhones finally began to outsell iPods. The quarterly sales of iPods, shown in Exhibit 9, make the pattern much clearer. The historical peak in iPod sales occurred in the last quarter (Christmas season) of 2008. The second quarter of 2009 was the first time that iPod sales were below their sales one year earlier. Bearing in mind that in this period most smart phones were not used for Internet access, these data indicate that smart phones did not begin to have a competitively significant effect on the market for portable digital media players until after the end of the class period.

The other product that is a candidate to be in the relevant market for portable digital media players is portable CD players. My search of publications and documents from Apple leads me to conclude that portable CD players had become obsolete and unimportant before the beginning of the class period. According to one review, portable CD players “have almost completely lost market share to MP3 players. However, for those who have a collection of CDs and no desire to spend hours converting them to digital format on a computer, portable CD players are still available.”⁴⁶ *Consumers Reports*, the publication of Consumers Union, has not reviewed portable CD players since 2002, and its current web site shows no hits for a search on “portable CD

46. “Portable CD Players Reviews,” *ConsumerSearch*, January 2008, at <http://www.consumersearch.com/portable-cd-players/review>.

players.”⁴⁷ CNet has not reviewed a portable CD since before the beginning of the class period.⁴⁸ No products other than portable digital media players were considered by Apple in the documents from which Exhibits 2-7 were created. Thus, there is no evidence that CD players imposed a competitive constraint on portable digital media players in the relevant time period for this litigation.

Digital Audio Files

The closest substitutes for iTS are the web sites that offer permanent downloads of audio recordings that are distributed by the major record companies. The labels that are distributed by the then five, now three, major record distribution companies account for 85 to 90 percent of all sales of sound recordings. Internet sites that sell downloads of recordings from the four major record distribution firms include Amazon.com, BuyMusic, Napster, Puretracks, WalMart and Zune.⁴⁹ During the class period Rhapsody also sold downloads, but they abandoned this business on April 1, 2013. Several sites entered the download business before iTS, but iTS was the first site that offered a full catalog of digital audio recordings from all of the major record distribution companies. Some other online sellers of permanent downloads, such as eMusic and Ruckus, were not close substitutes for iTS during the class period because they offered downloads only from independent distributors or artists who had no distributor. Most download sites,

47. See <http://www.consumerreports.org/cro/search.htm?query=portable+cd+players>.

48. A search for “editors review portable CD players” on CNet obtained no relevant hits. See http://reviews.cnet.com/1770-5_7-0.html?query=editors+review+portable+cd+player&tag=srch&searchtype=products.

49. For descriptions and reviews of audio download sites, see <http://music-download-review.toptenreviews.com/>. I have not included the sites that may not be legal.

including those that offer recordings from the major labels, differentiate their product by being the exclusive distributor for some independent artists or labels, and as a result even the largest download vendors are not perfect substitutes for each other. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED].⁵⁰

Two other products are potential competitive substitutes for downloads of digital audio files: physical recordings, which for the history of iTS have been dominated by CDs, and streaming on-demand or customized Internet services [REDACTED]

[REDACTED]

[REDACTED].⁵¹ [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

An on-demand service (an example is Spotify), sometimes called the “celestial jukebox,” allows a customer to create specific play lists of sound recordings.⁵² Each play

50. “iTunes Competitive Landscape,” October 2007, AIIA00187783-823 at AIIA00187795.

51. *Defendant Apple Inc.’s First Amended Objections and Answers to Plaintiff’s Second Set of Interrogatories 9-13*, p. 6.

52. For more information about on-demand services, see Rick Marshall, “*Oh Mercy*:

list is akin to a CD except that the content of the list is selected by the user. A customer can then listen to a play list on a personal computer or an Internet-enabled wireless communications device (a smart phone or a tablet computer). Among Internet streaming options, on-demand services that are available on a mobile wireless device are like playing audio files on an iPod. And there is evidence that on-demand services have substituted for downloads. A recent joint study by NPD Group and the National Association of Recording Merchandisers (NARM) concluded that on-demand music services detract from sales of sound recordings.⁵³ In response to this study, ST Holdings, which owns about 200 record labels, notified Spotify as well as Napster, Rdio and Simfy that it no longer will allow its recordings to be included in their services due to their detrimental effect on sales.⁵⁴ Hence, the available evidence supports the conclusion that these services are part of the relevant market that includes iTS.

The problem is that on-demand services that were supported by mobile devices had no significant number of customers during the class period: only 1.8 million subscribers in 2011 and 3.4 million subscribers in 2012.⁵⁵ The oldest Internet streaming service is Rhapsody (originally Listen.fm), which acquired rights to recordings from the

How On-Demand Interactive Streaming Services Navigate the Digital Music Rights Licensing Landscape,” November 21, 2012, at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2179111.

53. “Study: Spotify is Detrimental to Music Purchasing,” *Digital Music News*, November 15, 2011, at http://www.digitalmusicnews.com/permalink/2011/111115/cannibal#VIZ3-3IxRZUcRMwuQcs_9g.

54. Corey Tate, “Rdio, Spotify and Napster Lose 200 Record Labels Due to NARM Study,” *Spacelab*, November 19, 2011, at <http://www.thespacelab.tv/spaceLAB/2011/11November/MusicNews-064-Rdio-Spotify-Napster-NARM-NPD.htm>.

55. Joshua P. Friedlander, “News and Notes on 2012 RIAA Music Industry Shipment and Revenue Statistics,” RIAA, at http://www.riaa.com/keystatistics.php?content_selector=2008-2009-U.S-Shipment-Numbers.

major record companies in 2002. But Rhapsody could not support access by mobile telephones until 2011 with the release of Rhapsody 5.0, the company's version of a digital media player. Likewise, Spotify, currently the most popular on-demand service, was not launched in the U.S. until the summer of 2011. MOG ("Music On the Go") was not available on mobile phones until December 2009.

The reason that on-demand services only recently have been supported on mobile wireless devices is that the quality of the wireless network only recently was good enough to allow high-quality live audio streaming. Whereas a download does not need to be heard as the recording is being received, an on-demand streaming service requires that the transmission rate of the audio file be fast enough to support high-quality sound reproduction. At the beginning of the class period, U.S. wireless carriers had rolled out 3G digital wireless service. The original 3G wireless provided data transmission at a peak rate of 200 kilobits per second (kbs),⁵⁶ which was a crucial step in developing audio programming for mobile wireless devices because it allowed audio services to equal or surpass the quality of FM radio. Today, U.S. wireless carriers employ 3G wireless technologies that are capable of sustained bit rates of more than a megabit per second (mbs) and are in the process of upgrading their networks to 4G technology.⁵⁷ 4G service can sustain substantially higher data speeds, thereby making mobile wireless devices capable of receiving video transmissions that are comparable to DVDs and high-

56 See James Martin, "Mobile Computing: The Newest Wireless Technology," *PC World*, November 14, 2002, at http://www.pcworld.com/article/106149/mobile_computing_the_newest_wireless_technology.html.

57. Federal Communications Commission, *Annual Report and Analysis of Competitive Market Conditions With Respect to Mobile Wireless, Including Commercial Mobile Services*, June 24, 2011, pp. 72-78 (henceforth *Mobile Wireless Report*).

definition cable television.

Reflecting the lack of impact of these sites during the class period, a list of the best web sites of 2009 includes only one on-demand site – Spotify – and notes that it is available only in Europe.⁵⁸ Billboard, the leading trade publication for the music industry, did not modify its method for measuring hit records to take into account on-demand streaming services until March 14, 2012.⁵⁹ To explain why this new feature was adopted, Billboard quoted the Vice President of the NARM, who stated” “The last year has seen an explosion of both subscribers and traffic to music subscription services, and the business is now contributing meaningfully to the music industry's growing digital music revenues.” Thus, on-demand services cannot have had any competitive effect on iTunes until long after the end of the class period.

A customized service (examples are Last.fm and Pandora) allows consumers to list artists and songs that they like and then customizes the play list to suit the consumer's preferences. Pandora, the most popular customized streaming service, sponsors the Music Genome Project, a computer algorithm for classifying music and determining a consumer's music preferences.⁶⁰ Last.fm's algorithm for customizing play lists is called

58. Adam Fisher, “The 50 Best Websites of 2009,” *Time*, August 24, 2009, at <http://www.time.com/time/specials/packages/completelist/0,29569,1918031,00.html>. The list also includes two customized streaming services, Pandora and Last.fm, which are discussed elsewhere in this report.

59. Billboard Staff, “Hot 100 Impacted by New On-Demand Songs Chart,” *Billboard*, March 14, 2012, at <http://www.billboard.com/articles/news/502020/hot-100-impacted-by-new-on-demand-songs-chart>.

60. See <http://www.pandora.com/about/mgp>.

“scrobbling.”⁶¹ On these sites consumers indicate whether they like or dislike a recording as it is played. The computer algorithm uses this information to construct an ever-evolving play list.

Most likely customized sites are not close enough substitutes for play lists that are constructed by the consumer to be in the same relevant market as download and on-demand sites. The play list includes recordings that are new to the user and that the user may wish to buy. Thus, customized music services are more like preprogrammed radio stations (terrestrial and satellite) and webcasting than like on-demand services that allow a consumer to control the play list.

Preprogrammed stations are well-understood to promote record sales, not to substitute for them. For decades record companies have encouraged terrestrial stations to play their sound recordings by giving stations free copies of recordings, providing promotional materials for new releases, and making artists available for interviews. Record companies also have used “payola” – cash payments and other gifts to disk jockeys and program directors – to induce radio stations to play their recordings.⁶² FCC rules prohibit broadcasters from accepting fees to promote a particular sound recording or artist without disclosing that the promotion is an advertisement, regardless of whether the fee goes to the station owners or to an employee who can influence program content.⁶³

The FCC’s rules are not mere window dressing. Enforcement actions for these

61. See <http://www.last.fm/about>.

62. See Ronald Coase, “Payola in Radio and Television Broadcasting,” *Journal of Law and Economics* Vol. 22, No. 2 (October 1979), pp. 269-328.

63. The FCC’s rules are described at <http://www.fcc.gov/guides/payola-rules>.

rules occur regularly.⁶⁴ In 2007 the FCC settled complaints against four large groups of radio stations (CBS, Citadel, Clear Channel and Entercom) for accepting cash and other considerations from record companies in return for playing their sound recordings.⁶⁵ The four groups agreed to pay a total of \$12.5 million to the FCC. In 2011, the FCC settled a complaint against Emmis Austin Radio Broadcasting for accepting payola from a record store, a concert venue and a booking agent to play recordings by a heavy metal rock band that was appearing locally.⁶⁶ Bribing radio station employees and risking FCC sanctions would make no sense if record companies did not believe that radio play time induced greater sales of sound recordings. Additional evidence that non-interactive streaming services are not regarded as substitutes for permanent sales is that the NARM study did not identify any customized service as detracting from record sales, and no record company or artists have refused to allow their recordings to be played on these services.

In any event, even if non-interactive streaming services are substitutes for digital downloads today, they were not effective competitors during the class period for the same reason that on-demand services were not. These services only recently became available on mobile devices. Pandora released its first application that enabled consumers to

64. Since 2007, the FCC has undertaken 17 enforcement actions with respect to this rule. See <http://transition.fcc.gov/eb/broadcast/sponsid.html>.

65. Federal Communications Commission, "Broadcasters Pay \$12.5 Million to Resolve Possible 'Payola' Violations," April 13, 2007, at http://transition.fcc.gov/eb/News_Releases/DOC-272304A1.html.

66. Federal Communications Commission, *Order: In the Matter of Emmis Austin Radio Broadcasting Company, L.P.*, File No. EB-06-IH-2944, July 22, 2011, at <http://transition.fcc.gov/eb/Orders/2011/DA-11-888A1.html>.

access this music service on a mobile phone in 2008.⁶⁷ Most use of Pandora today is on mobile devices, but that is a recent event. Pandora estimated that mobile wireless users accounted for 50.5 percent of its listener hours in 2011, but only 4.6 percent in 2009.⁶⁸

The insignificance of on-demand and non-interactive digital streaming services is documented in Exhibit 1, which shows the breakdown of revenues to the record industry from various sources. Most revenue from digital sales is from downloads. In 2012, digital downloads accounted for \$2.9 billion in industry sales, compared to \$1.0 billion from all other digital sources, including satellite broadcasting and preprogrammed webcasting.⁶⁹ The latter accounted for 15 percent of industry revenue in 2012, but only 4 percent in 2008 and 5 percent in 2009. Moreover, as shown in Exhibit 1, revenue from digital sources other than downloads did not change substantially from 2006 through 2008, which includes all but the last quarter of the class period. Thus, digital streaming services were too small during the class period to be a competitive restraint on audio download services.

The last candidate for inclusion in the relevant market for downloads of audio files is the sale of physical copies of sound recordings. Exhibit 1 also shows that sales of physical copies have declined substantially for the past decade. During the period in which revenues from downloads grew substantially (2004-2007), physical copy sales fell by \$4 billion. During the period that revenues from downloads grew less rapidly and then stabilized (2007-2010) sales of physical copies dropped another \$4 billion. Clearly

67. *Ibid.*, p. 44.

68. Pandora Media Inc., *Form 10-Q for Quarter Ended July 31, 2011*, September 2, 2011, p. 33.

69. Friedlander, *op. cit.*

CDs are in decline, but the issue is whether the decline indicates that CDs are a sufficient competitive constraint on downloads of digital audio files to be included in the relevant market. The continued decline after download sales stopped growing indicates that CDs are not constraining sales of downloads. If they were, then download sales would have captured a large share of the drop in CD sales after 2007, which they have not.

The main attraction of physical copies of audio files is that they generally have higher sound quality, although as download speeds over the Internet increase, this advantage is likely to disappear. For several other reasons physical copies are not close substitutes for downloads. One reason is that the process of buying downloads is more convenient. Downloads can be obtained immediately, rather than requiring a trip to a brick-and-mortar store or a wait for delivery if purchased from an Internet vendor. Another reason is that most recordings are not available as physical copies except as part of a CD. Consumers of downloads can create their own personalized albums from the millions of songs that are available on a download web site. A final advantage of downloads is that storage requires much less space, which is of greater importance to consumers who have extensive collections of recordings.

A great deal of academic research has focused on whether music on the Internet, especially illegal file-sharing, is responsible for the decline in sales of CDs. A comprehensive survey examines nearly 80 studies on the relationship between file-sharing and CD sales.⁷⁰ This issue is relevant to whether digital downloads compete with CDs because illegal file-sharing is a form of permanent download at the very attractive

70. Volker Grassmuck, "Academic Studies on the Effect of File-Sharing on the Recorded Music Industry: A Literature Review," available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1749579.

price of zero – but the very unattractive prospect of being detected and sued by the record industry. The survey finds that the research on whether file-sharing is responsible for the decline in CD sales is inconclusive, but “one lone author – against all basic intuition and common sense – attributes the entire decline in recorded music sales and even more to file-sharing” (p. 30).

So what explains the decline in CD sales? The research survey identifies several causes: (1) a switch in retail sales of CDs from large inventory music stores to low inventory, big box retailers; (2) a shift in record company strategy to release fewer records and to focus more on releases by star performers; (3) a temporary sales boom in the 1990s when consumers replaced libraries of vinyl records and audio tapes with CDs; (4) a mistaken decision by the record companies to adopt DRM technology and to try to use it to move to a form of metered use (limiting plays, limiting devices), capped by the decision by Sony-BMG to include a “root kit” on CDs that enabled the company to control a customer’s computer; (5) the abandonment of the single recording release in favor of albums; and (6) the rise of a robust, Internet-based market for used CDs.

A subsequent study since the survey was completed shed a little more light on the issue.⁷¹ This study uses a survey among French consumers to inquire whether illegal (free) file-sharing competes with each of the different types of legal Internet music services as well as CD sales. The study has several interesting findings. First, free (legal), advertising-supported streaming services have caused a substantial reduction in illegal file-sharing. Second, Internet streaming services have no effect on CD sales but

71. Godefroy DangNguyen, Sylvain Dejean, and Francois Moreau, “Are Streaming and Other Music Consumption Modes Substitutes or Complements?” March 16, 2012, at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2025071.

actually promote on-line download sales. In brief, the positive effect of sampling new material outweighs the negative substitution effect.

The robust conclusion from the research literature is that Internet music is not a primary cause of the decline in sales of physical recordings. The finding that streaming has no effect on CD sales but promotes downloads implies that downloads are not competitive substitutes for either CDs or streaming services.

Market Power

Market power is the ability to control prices or exclude competitors. Economists use both direct and indirect measures of market power.

Direct measures of market power include the profits and mark-ups of price over average variable cost and incidents in which a competitor was driven from the market or abandoned an attempt to enter the market as a direct result of the defendant's actions.⁷² A firm with market power is able to set price-cost margins and to earn profits that exceed an appropriate competitive benchmark and also is able successfully to defend its sales and excess profits against attempts by competitors to capture a larger market share. A substantial, sustained increase in price-cost margins for a profitable product is a reliable indicator of increased market power because, in a competitive market, prices are driven towards the long-run average cost of production. Hence, if competitive conditions in a market do not change, price changes through time should reflect only changes in costs.

72. Another direct indicator of market power is the own-price elasticity of demand (the responsiveness of sales to price) for the reference product; however, a reliable estimate of own-price elasticity is not feasible here.

Margin Analysis

Profit margins are regularly used by economists and financial analysts to ascertain the market power of a firm. One standard technique is to measure “pass-through” of a change in variable costs.⁷³ Another standard technique is to examine whether a firm’s percentage mark-up changes in response to an event that potentially could affect the firm’s market power without affecting its costs or product quality.

For iTunes, Apple has produced only highly aggregated data about revenues and costs. These are not sufficient to undertake a margin analysis for downloads of audio files, which are the relevant product in this case. Hence, other methods of ascertaining Apple’s market power in this product market are necessary.

For iPods, two sources of information are available for analyzing profit margins. One is publications that study Apple’s financial performance in electronic devices, and the other is data produced by Apple in discovery about revenues and costs by model.

Financial analysts regularly provide interpretations of data about Apple’s publicly reported sales, costs and profits. For example, one financial analyst reports that the price difference between two models of iPods that differ only in memory capacity is more than double the difference in cost.⁷⁴ This price difference could not be sustained in a competitive market, and therefore must be the result of market power. An academic analysis of the relationship between price and component costs finds that in 2006 Apple

73. Variable costs are the component of cost that depends on output and sales. A profit-maximizing firm will set the price of a product based on its marginal or incremental cost and its firm-specific elasticity (price responsiveness) of demand. The accounting cost data that most closely corresponds to marginal cost is average variable cost.

74. “The Mix Get Richer: New iPod touch & iPhone Capacities,” Credit Suisse, February 5, 2008.

earned higher margins on iPods than others earn on notebook personal computers.⁷⁵ This study is an example of using a “competitive benchmark” (here, notebook computers) to infer the presence of market power in another, technically similar product.

[REDACTED]

75. Jason Dedrick, Kenneth L. Kraemer and Greg Linden, “Who Profits from Innovation in Global Value Chains? A Study of the iPod and Notebook PCs,” *Industrial and Corporate Change*, June 22, 2009, at <http://icc.oxfordjournals.org/cgi/reprint/dtp032r1>. The authors state that a “key reason ... is that Apple’s control of the core software, proprietary standards and complementary infrastructure of the iPod enables it to retain greater profits, whereas a large share of the PC industry profits are siphoned off by Microsoft and Intel, whose ownership of valuable standards allows them to charge a considerable price premium.”

76. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] 77 [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Exclusion of Competitors

The evidence pertaining to the exclusion of competitors involves analyzing the success of attempts by competitors to offer products that directly compete with a reference product. The challengers against Apple were other online sellers of digital downloads and portable digital audio players.

In antitrust economics, the term “exclusion of competitors” means that the market shares of competitors were substantially less than otherwise would have been the case, not that competitors could not survive in the market. The core issue is whether the leading product was able to use market power to sustain super-competitive prices and a high market share that were not eroded by the entry of competing products.

The disabling of Harmony through iTunes 4.7 and 7.0 are an example of exclusion of a competitor. In 2006, RMS was a rapidly growing competitor against iTunes,

77. [REDACTED]

but the disabling of Harmony created a serious impediment to the sale of downloads to customers who purchased iPods with these features. An article about the rapid growth of Rhapsody at the time of Harmony's release was produced by Apple during discovery.⁷⁸ The expert report of Dr. David Martin that was submitted as part of plaintiffs' opposition to defendant's summary judgment motion discusses how iTunes 4.7 disabled Harmony. I understand from conversations with him that his expert report of April 8, 2013, will explain how iTunes 7.0 had the same effect.

[REDACTED]

[REDACTED]⁷⁹ Whereas the iPod is a very highly rated product, reviews of portable digital media players place several other brands in the same category. For example, CNet reviews give ratings to Creative Zen, Microsoft, SanDisk and Sony players that are comparable to the iPod ratings, with SanDisk frequently earning accolades as the best buy among all players. Yet for a decade, high ratings at CNet have not translated into an erosion of the market share of iPods. Apple has successfully maintained its high market share despite repeated entry from products of comparable quality. Of course, one cause of a high market share could be competitive prices; however, Apple's prices generally are higher than the prices of its competitors.

78. Apple_AIIA00325894-97.

79. [REDACTED]

[REDACTED]

Market Concentration

An indirect indicator of market power is seller concentration in the presence of barriers to entry. A measure of market concentration that economists commonly use is the Herfindahl-Hirschman Index (HHI), which equals the sum of the squares of the market shares of the firms in the market. In the presence of barriers to entry, an HHI exceeding roughly 2500⁸⁰ is regarded as sufficient to infer that large firms in the market possess market power, and an HHI between 1500 and 2500 is sufficient to “warrant concern” about the intensity of competition.⁸¹ In the presence of barriers to entry, the 2500 benchmark implies that a firm is likely to enjoy unilateral market (monopoly) power if its market share exceeds 50 percent.

Several private companies regularly collect data about market shares for audio downloads and portable digital media players.⁸² [REDACTED],

80. A market with four firms of equal size has an HHI of 2500.

81. *Merger Guidelines, op. cit.*, p. 19.

82. [REDACTED]

[REDACTED]

[REDACTED]⁸³ Data from these sources is reported in public sources, including financial analysts, trade associations, and trade publications. [REDACTED]

[REDACTED]

[REDACTED].

[REDACTED]

[REDACTED]

[REDACTED]⁸⁴ [REDACTED]⁸⁵

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

83. *Defendant Apple Inc.'s Supplemental Objections and Answers to Plaintiffs' Amended First Set of Interrogatories*, p. 9.

84. Philip Elmer-DeWitt, "How to Grow the iPod as the MP3 Market Shrinks," *Fortune*, January 20, 2008, accessed on <http://apple20.blogs.fortune.cnn.com/2008/01/29/beyond-the-incredible-shrinking-ipod-market/>.

85. Joe Wilcox, "Media2Go Team Gets Creative," *C/Net News.com*, March 13, 2003, reporting the iPods market share at the end of 2002 was 27 percent; Rob Walker, "The Guts of a New Machine," *New York Times*, November 30, 2003, reporting that iPods market share jumped to 56 percent in the summer of 2003 after the launch of iTunes; Mark Heflinger, "Zune MP3 Market Share up to 4%, Creative Drops to 2%," *Media Wire*, May 12, 2008, reporting that iPod's market share was 71 percent in early 2008, compared to 72 percent a year earlier.

As discussed above, some portion of cell phone sales should be included in the market for portable digital media players since smart phones began to be used as an MP3 player. A large survey of mobile subscribers in late 2011, long after the end of the class period, found that between 21 and 24 percent of mobile subscribers “listened to music” on their cell phone. Because webcasting and streaming services accounted for some of this activity,⁸⁶ these numbers substantially exceed the fraction of cell phone users who use their phone as an MP3 player. The proper indicator for Apple’s market power in portable digital media players includes only the share of smart phone purchases for which the buyer actually wants to use the device as a portable digital media player.

[REDACTED]

86. “comScore Reports December 2011 U.S. Mobile Subscriber Market Share,” comScore, February 2, 2012, at http://www.comscore.com/Insights/Press_Releases/2012/2/comScore_Reports_December_2011_U.S._Mobile_Subscriber_Market_Share.

[REDACTED]

[REDACTED]

[REDACTED] 87 [REDACTED]

[REDACTED] 88 [REDACTED]

[REDACTED]

[REDACTED] 89 [REDACTED]

[REDACTED] 90 [REDACTED]

[REDACTED]

[REDACTED] 91 [REDACTED]

The HHI in each market during the class period was substantially above the level that is used to indicate the presence of market power of the leading firm in the presence of barriers to entry. In the download market the HHI typically was above 5000, and in the market for portable digital media players, after taking account of smart phone sales, the HHI always exceeded 4000. Apple’s market shares of both iPod and iTunes during the class period were above the 50 percent threshold that is necessary for Apple to enjoy

87. [REDACTED]

88. Apple_AIIA00091049.

89. “Apple Market Share by Calendar Quarters Q1 2005 to Q2 2007” (Apple_AIIA_0712612).

90. “iTunes Market Share” (Apple_AIIA_00979727).

91. Apple_AIIA_00099408.

unilateral market (monopoly) power in the presence of entry barriers.

Barriers to Entry

In addition to market share information, the market structure approach to ascertaining market power also requires showing that conditions in the market are conducive to the exercise of market power. The most important of these conditions is the presence of barriers to entry. A barrier to entry is any condition that would prevent a firm from either entering a market or expanding its output in a market in which it is already present. Examples of barriers to entry are high fixed costs that require an entrant to sell a large amount of output at existing market prices in order to operate profitably and intellectual property rights that protect an incumbent from competition. Anticompetitive acts also can create a barrier to entry. An example is tying or bundling. In the presence of tying or bundling, an entrant must succeed in successfully producing both products, rather than only one, in order to compete in either market.

One form of entry barrier in the information technology sector is the high fixed cost of R&D that is necessary to create new products. High fixed costs are a barrier to entry because they require that a firm be able to set prices above average variable cost and achieve significant market share in order to find entry into a market attractive. Portable digital media players were a rapidly evolving technology throughout the class period, and the R&D effort necessary to produce each succeeding generation of players was a barrier to entry.

Intellectual property also can constitute a barrier to entry. For example, a major issue in this litigation has been whether the “crippleware” that is part of Apple’s digital

rights management system (for example, the code that prevented Harmony from playing FairPlay files that was introduced by iTunes 4.7 and iTunes 7.0) was a legitimate exercise of its intellectual property rights or an anticompetitive act to exclude competitors.

Regardless of the resolution of that issue, crippleware is an example of a barrier to entry.

Likewise, lock-in that is created by technical incompatibility also creates a barrier to entry. The effect of Apple's "walled garden" involving iTunes, iPods and iPhones, and iTunes digital media player creates switching costs for users. The lock-in from switching costs reduces the intensity of competition partly because it creates a barrier to entry.

During the class period, in order to play digital recordings acquired from iTunes on a portable digital media player, a consumer was forced to buy an iPod because only an iPod could play recordings in the DRM-protected FairPlay format that is used by iTunes. Even after Apple stopped selling recordings encrypted with DRM-protected FairPlay in 2009, consumers who had a pre-existing library of digital recordings purchased from iTunes were precluded from playing those files directly on any portable digital player other than an iPod unless they paid Apple to upgrade their files to the iTunes Plus format or burned their old files to a CD and reloaded them on their personal computer.⁹²

As discussed in the expert report of Dr. David Martin, RealNetworks attempted to compete against iTunes by inventing a digital media player that could load and play the digital audio recordings offered by its RMS download service on an iPod. RealNetworks was thwarted in this effort when the defendant changed its encryption code to defeat the compatibility between Harmony and iPods. This conduct is an example of how

92. See "iTunes Store: iTunes Plus Frequently Asked Questions (FAQ)" on Apple's website, <http://support.apple.com/kb/ht1711>. iTunes users can upgrade a previously-purchased song to a DRM-free version for \$0.30 or an album for 30% of its price.

perpetuation of technological incompatibility creates a barrier to entry in the market because it requires a competitor to experience recurring costs to reverse engineer an ever-changing technical incompatibility.

The introduction of Harmony enabled iPod owners to download audio recordings from an Internet vendor other than iTunes. Harmony, combined with lower prices on RMS, increased demand for audio downloads from RMS, causing Rhapsody's market share to double from 10% to 20%.⁹³ Thus, the initial effect of Harmony was to reduce the barrier to entry against iTunes and to cause the market share of iTunes to fall.

The long run effect of a functioning Harmony also would have been to increase competition against iPods by reducing the extent to which iPod users were locked in to iTunes. As discussed elsewhere, lock-in increases the market power of a vendor over its customers, but it also makes the vendor a less effective competitor for customers of other vendors. Because lock-in is a two-way street (also involving "lock-out" of customers of other vendors), a strategy of creating lock-in through technical incompatibility is more attractive to a vendor with a very large share of the installed base.⁹⁴

[REDACTED]

[REDACTED]⁹⁵ [REDACTED]

93. Jefferson Graham, "Real Says Digital Song Sale Doubled Market Share", *USA Today*, September 9, 2004 (see Apple_AIIA_00090447-79). This article describes how RealNetworks rolled out Harmony with a three week sale at \$0.49 per song on Rhapsody. RealNetworks planned to keep the \$0.49 per song price for weekly top 10 singles.

94. [REDACTED]

95. [REDACTED]

from other Internet vendors and over four years before iTunes switched to DRM-free audio recordings. As a result, the proportion of audio downloads that were incompatible with competing portable digital media players would have begun to decline years earlier.

If iPod users who purchased audio recordings from iTunes and from RMS using Harmony decided to replace an old iPod, the cost of switching to a competing product would have been lower had Harmony survived, thereby intensifying competition between iPod and other brands. Given the rapid technological progress in portable digital media players during the class period, Harmony plausibly would have increased competition against iPods substantially before DRM-free audio recordings became available. By updating iTunes to block interoperability with Harmony, Apple preserved the lock-in of iPod owners to iTunes and iPods.

The switch to DRM-free audio recordings is likely to have reduced the lock-in of iPod users. The transition to DRM-free content was slow, proceeding for nearly two years. In April 2007, EMI announced a “premium” version of downloads of audio files (singles, but not albums, selling for a higher price), and iTunes was the first to offer these downloads, with others expected to follow in a few weeks.⁹⁸ In May 2007, iTunes introduced iTunes Plus, which initially offered recordings from EMI, some independent record labels, and some unaffiliated artists in an unprotected format. iTunes Plus recordings could be loaded onto some portable digital media players other than iPods, although doing so required manipulation of the files using both iTunes and another digital media player. Other audio download sites also made deals with EMI, but other sites

98. “EMI Launches DRM-Free Superior Sound Quality Downloads Across Its Entire Digital Repertoire,” *Webwire*, April 3, 2007, at <http://www.webwire.com/ViewPressRel.asp?aId=31281>.

began to offer DRM-free EMI files in August.

Also in August 2007, Universal announced that it would conduct an experiment from August 2007 to January 2008, in which it would release some DRM-free audio recordings to several audio download services, including Amazon.com, Best Buy, Google, RMS and WalMart.⁹⁹ Several download sites were launched in August and September that offered some Universal DRM-free recordings.

Universal and the other two major distribution companies, Sony-BMG and Warner, committed to sell a large number of audio recordings without DRM protection between late December 2007 and early January 2008, and the transition to offering a large inventory of DRM-free audio recordings by audio download services was complete in March 2008. In January 2009, Apple announced that it would sell audio recordings from all of the major distribution companies without DRM protection, and by April 1, 2009, a large repertoire of audio recordings could be purchased on iTunes without DRM protection. As a result, audio files from many sites can be loaded, catalogued and played on an iPod, and DRM-free audio recordings from iTunes can be played on other portable digital media players, although doing so requires using two digital media players.

The widespread availability of DRM-free audio downloads should have reduced the lock-in of iPod owners to both iTunes and replacement iPods. DRM-free audio recordings enable iPod users to buy audio recordings from competitors of iTunes. As time progressed, a larger proportion of a consumer's library, and all of the more recent acquisitions, were in a DRM-free format. For some users, the value of older DRM-

99. Colleen Bowen, "Universal Launches DRM-Free Music Test," *TWICE*, August 10, 2007, at http://www.twice.com/article/258659-Universal_Music_Launches_DRM_Free_Music_Test.php.

protected recordings probably will decline, in which case some users may decide that the loss of the ability to store and play old audio recordings on a new portable digital media player is no longer an important reason not to replace an old iPod with another brand.

Conclusions on Market Power

Based on the evidence about the nature of the products at issue in this litigation, the performance of the products in the market, and Apple's internal documents and data, I conclude that Apple enjoyed market power in the relevant markets for downloads of digital audio files and portable digital media players. The crucial evidence here is the presence of persistent monopoly power in iPods. The design of the iTunes digital media player and iTS created a lock-in to iPods that made the latter products largely immune to intense competition on both price and quality from other electronics firms. Whereas the initial attainment of monopoly power in iPods arose because of the first-in advantage in downloads of digital audio files that was given to Apple by the record companies, Apple's DRM technology played a critical role in maintaining and enhancing that advantage. The iTunes 7.0 update re-established the lock-in that had been eroded by Harmony, thereby enhancing the barrier to entry in portable digital media players due to lock-in. As a result Apple enjoyed both a high market share and a record high profit margin iPods after Harmony was disabled through the end of the class period. The effect of this lock-in is quantified in the damages analysis elsewhere in this report.

ANTICOMPETITIVE SOURCES AND EFFECTS OF MONOPOLY POWER

The issue in this litigation focuses on conduct by Apple in 2006 and 2007 to raise

switching costs from iPods to competing portable digital media players. The plaintiffs' allegation pertaining to this conduct has two components. The first is a test from antitrust economics as to whether conduct that creates lock-in is anticompetitive. The second is the empirical question of the quantitative significance of the lock-in effect as measured by its effect on market prices. In this case the quantifiable harm to competition is the overcharge on iPods that was the result of the conduct that created lock-in.

Tests for Anticompetitive Conduct

If a firm enjoys market power, economic analysis can be used to determine whether its market power is due all or in part to anticompetitive acts. Firms may enjoy market power due to "superior foresight and efficiency," i.e., their products are cheaper and/or better because they have superior technology and/or management. For example, innovations that are protected by valid intellectual property rights or that otherwise are difficult for competitors to copy can be a source of market power. Likewise, if the production technology in an industry exhibits economies of scale that are sufficiently strong that only a small number of firms can achieve the minimum efficient scale of production, firms are likely to enjoy market power and to earn excess profits. In antitrust economics, obtaining market power from these sources is not anticompetitive.

Firms also may acquire or maintain market power by anticompetitive means. The ultimate test for whether conduct is anticompetitive is whether it harms consumers. In antitrust economics, conduct is regarded as unambiguously anticompetitive if it increases or maintains market power, does not improve the quality or diversity of products available, is unrelated to the legitimate protection of intellectual property rights, and

requires costly action by the firm that undertakes it. An act may be anticompetitive even if it provides benefits to consumers and is not costly to the firm with market power, but only if no reasonable alternative means can obtain the same benefits to consumers.

Technical Incompatibility as an Anticompetitive Source of Market Power

Apple's conduct to re-establish the lock-in of iPod owners was anticompetitive if it was costly to implement, provided no benefit to consumers, but increased profits only because it increased Apple's market power. The expert report of Dr. David Martin shows that the changes in the DRM system that were associated with iTunes 7.0 and iTunes 7.4 produced no benefits to consumers. But the creation of technical incompatibility without a consumer benefit has a direct cost and an opportunity cost.

The direct cost is the incremental cost of creating incompatibility. The issue here is not that the defendant had to incur costs to implement its proprietary file format, but that the defendant was forced to incur additional costs for actions that had no purpose other than to create or maintain incompatibility. Lines of code are also a rough indicator of the cost of software. [REDACTED]

[REDACTED]

[REDACTED]

Opportunity cost in this context refers to the sacrifice of sales in one product in order to create and maintain incompatibility between its competitors and the other product. The issue here is whether a vendor that owned only a download site (e.g., iTS) and the software that was needed to access that site (e.g. iTunes) has a profit incentive to make that site compatible with only one brand of portable digital media player. The

answer, of course, is no – an independent owner of iTS would want to make the site accessible to enough portable digital media players to ensure that the player market was competitive. Indeed, RealNetworks pursued this path by working with several manufacturers of portable digital media players to produce products that could access RMS and its streaming service, Rhapsody. Harmony was a component of this strategy as it sought to make iPods compatible with RMS.

The same argument applies to an independent supplier of iPods. To maximize sales, a stand-alone supplier of iPods would make the product compatible with download sites other than iTS. An independent iPod supplier would like to lock-in iTS customers by making iTS compatible only with iPods, but it would not want to prevent customers of competing download sites from buying iPods. For this reason, an independent iPods supplier would not take actions to prevent RMS customers from using iPods.

The benefits of lock-in to Apple consisted of increased profits from the lock-in. As discussed elsewhere, the market share of iTS hit an historical low after Harmony was released, but iTS then experienced a record market share and profit margin after Harmony was disabled and the incompatibility between RealPlayer and iPods was re-established. These additional sales and profits arose despite the fact that, as discussed by Dr. Martin, the changes in iTunes 7.0 did nothing to benefit consumers by improving the performance of iTS or iPods.

Harm to Competition

In antitrust economics, “harm to competition” by a seller with market power refers to reductions in the welfare of consumers. In this litigation one alleged harm to

consumers is higher prices for iPods. The *Amended Complaint* alleges that because it excluded actual and potential competition by updating its software to preclude interoperability, Apple was able to maintain and enhance its market power in the relevant market for portable digital media players. As a result, plaintiffs allege, the prices of iPods were higher than they would have been in the absence of the defendant's anticompetitive acts.¹⁰⁰ This effect is the source of damages, so the discussion of the quantification of this harm is discussed in the section about damages. Suffice to say here that damages are calculated from an econometric model of iPod pricing that quantifies the effect of the lock-in that was created by disabling Harmony. The econometric model also quantifies the pro-competitive benefits arising from the introduction of Harmony and the end of DRM-protected audio files. This analysis shows that the magnitude of the pro-competitive benefit of DRM-free audio not only was substantial, but was greater than the anticompetitive harm due to iTunes 7.0.

Consumers also can suffer financial harm in ways that normally are not included in the calculation of damages. One example is the "dead-weight loss" arising from higher prices.¹⁰¹ Dead-weight loss is the loss of welfare arising from the reduction in output that occurs when prices exceed the incremental cost of production. An approximation of dead-weight loss is $\frac{1}{2}(P_m - P_c)(Q_c - Q_m)$, where P_m and P_c are the prices under monopoly and competition, and Q_m and Q_c are the quantities sold under monopoly and competition.

Because the conduct at issue in this case caused iPod prices to be higher, sales of

100. *Amended Complaint*, pp. 16-17.

101. Christopher R. Leslie, "Antitrust Damages and Deadweight Loss," *Antitrust Bulletin*, Vol. 51, No. 3 (Sept. 2006).

iPods thereby were lower. Replacement customers, who account for about half of iPod purchases, are likely to be especially sensitive to changes in price. Because they already enjoy the services of an older model, they have less to gain from purchasing a new model than a customer who does not have a portable digital media player. The dead-weight loss here arises because customers respond to higher prices by increasing the duration of the replacement period.

Once DRM-free audio files became available, consumers could overcome lock-in by repurchasing audio files that had been protected by FairPlay. These consumers would not be included in the damage calculation in this case if they purchased DRM-free files and then switched from an iPod to another player, but they still would have suffered harm. [REDACTED]

Defendant's anticompetitive acts also can harm consumers by reducing the intensity of competition among other firms in the market. These firms may charge higher prices for other products in the relevant market, either because they cannot take away a significant amount of business from dominant incumbents by lowering their prices or because the market power of dominant firms prevents them from achieving scale economies that would lead to lower prices if the market were more competitive.

One way that lock-in can cause harm to competition is by slowing technological progress. The incentive to innovate is provided by the sales that a firm expects to make if

it produces a new product with lower cost, higher quality and new features. Lock-in reduces expected sales from innovation because switching costs increase the incremental value of a new product that is necessary to induce locked-in customers to switch. Hence, lock-in reduces the incentive to innovate. A 2012 review of portable digital media players states: “If you can save money by buying last year's model, go for it. The innovation in MP3 players has been flat for years and a 2011 MP3 player is going to work just as well as one released today.”¹⁰²

Business Justifications

A business justification is a benefit to consumers arising from an act that reduced competition. Higher profits and greater sales are *not* business justifications. Instead, an act that causes anticompetitive harm is reasonable if it provides benefits to consumers that cannot be obtained by any reasonable alternative, less anticompetitive means.

Although the business justifications that Apple will offer at trial have not yet been submitted, the defendant’s submissions earlier in this litigation assert the following justifications. First, maintaining incompatibility between Apple’s products and its competitor’s products benefited consumers because “Apple’s products worked better together than with competitors’ products.”¹⁰³ [REDACTED]

[REDACTED]

[REDACTED]

102. Donald Bell, “MP3 Player Buying Guide,” *CNET Reviews*, November 5, 2012, at <http://reviews.cnet.com/mp3-player-buying-guide/>.

103. *Apple’s Reply in Support of Motion to Dismiss or, Alternatively, for Summary Judgment*, p. 1.

[REDACTED] 104

Third, preserving the interoperability established by Harmony (or any other would-be competitor) would have required continued cooperation between Apple and its rivals.¹⁰⁵

Apple's asserted product quality justification is common in antitrust cases involving technological incompatibility.¹⁰⁶ In *U. S. v. Microsoft*, the defendant argued that Internet Explorer was tied to Windows for the purpose providing higher quality by integrating the two products. The U. S. government contested this claim by arguing that Internet Explorer and Windows were not integrated in any meaningful way and that bundling them actually reduced the quality of Windows.¹⁰⁷ In this litigation, there is no evidence in the documents that have been produced by Apple in discovery that iPod users experienced any technical difficulties loading RMS files on an iPod.

[REDACTED]
[REDACTED]
[REDACTED]

[REDACTED]¹⁰⁸ All four major record distributors have submitted

104. *Ibid.*

105. *Ibid.*, pp. 1-2.

106. [REDACTED]

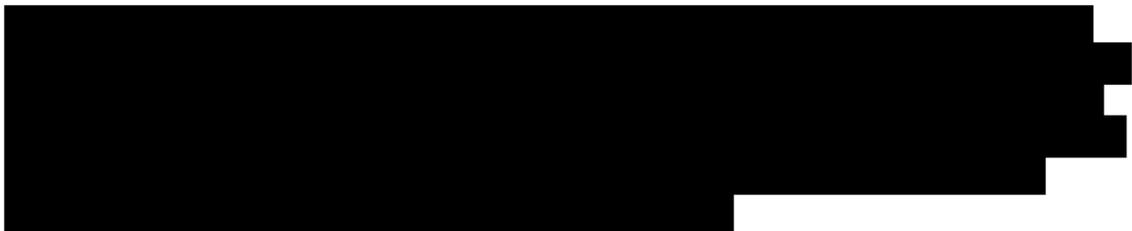
107. For a more complete discussion of this issue, see *Findings of Fact, U. S. v. Microsoft*, U. S. District Court for the District of Columbia, and the decision in the same matter by the U. S. Court of Appeals for the District of Columbia.

108. [REDACTED]

declarations stating this same point.¹⁰⁹ Harmony did not strip DRM, so the distributors' interests were not adversely impacted by its allowing interoperability with iPods.¹¹⁰

Apple's claim that maintaining compatibility would require cooperation with its competitors requires a technical analysis of the software upgrades that Apple used to prevent iPods from playing audio recordings that were acquired from Internet vendors that competed with iTunes. The problem with this claim is that RealNetworks managed to produce Harmony and to keep it operating during two periods, one lasting more than a year, without cooperation from Apple. In addition, the discovery cited elsewhere and by Dr. Martin indicates that Apple's software updates targeted Harmony and other programs that allowed iPod users to buy audio downloads from other sites.

Most competitors do not sell products in all of the relevant markets. Instead, they sell separate compatible products notwithstanding the alleged advantages of buying everything from a single vendor that are asserted by Apple. Among the firms that



109. *Declaration of Lawrence Kamusher (Sony), Declaration of Amanda Marks (Universal), Declaration of Mark Piibe (EMI), and Declaration of Howie Singer (Warner)* all in support of Plaintiffs' Opposition to Apple's Motion for Summary Judgment. See also "Warner Music Group Corp. F1Q07 Earnings Call," February 8, 2007 in which Warner Music Group CEO, Edgar Bronfman, states that Warner wants interoperability. "By far the larger issue for consumers in the music industry is interoperability. As a content company, we of course want consumers to seamlessly access our music and to use the music they have purchased on any platform and with any service, physical or digital. The issue is obscured by asserting that DRM and interoperability is the same thing. They are not. To suggest that they cannot co-exist is simply incorrect."

110. See *Apple_AIIA_00090471* and *Deposition of Eddy Cue*, p. 123.

participate in these markets, only Apple and Microsoft sold products that were technically incompatible with the products of competitors.¹¹¹

The analysis of business justifications must address whether consumers are harmed by the opportunity to deal with multiple vendors for each product (rather than only for the group of products), and whether the opportunity for choice among vendors of products in each relevant market offsets the benefit, if any, of integration from a single vendor. Consumers normally do not need vendors to protect them against considering and then rejecting a marketing message that seamless integration is valuable.

In the past decade, after the Microsoft case ended, two new wireless-enabled computers – smart phones and eReaders/tablet computers (initially separate products but now converged) – were enthusiastically received by consumers. Apple is successful in both products, but both markets are much more competitive than the market for portable digital media players, and both markets seem destined to be dominated by Google’s Android operating system, which supports many brands of products.

In smart phones, many brands of smart phones use Android, the most successful of which is the Samsung Galaxy. The share of smart phones that use Android rose from 51 percent in the fourth quarter of 2011 to 71 percent in the fourth quarter of 2012, while Apple iOS (the operating system for the iPhone), fell from 24 percent to 21 percent.¹¹²

111. Initially, Microsoft’s Windows media player software, online music store, and Zune portable digital media player were compatible with the products of all vendors in the relevant markets other than Apple. In 2006, Microsoft developed new versions of all three products, all named Zune, that, like Apple’s products, were incompatible with the products of other vendors, and closed its MSN Music Store, which had sold downloads in DRM-protected recordings in the WMA and WMV formats for use on multiple players.

112. Chuck Jones, “Android Solidifies Smartphone Market Share,” *Forbes*, February 13, 2013, at <http://www.forbes.com/sites/chuckjones/2013/02/13/android-solidifies->

Among Android smart phones, 47 percent are accounted for by Samsung and 37 percent are accounted for by Kindle, the eReader from Amazon.¹¹³

In tablet computers, the iPad, being the first product of its kind, had a first-in advantage that was similar to the iPod after iTS was introduced, but Apple's market share is now below half and falling as others have entered with quality products.¹¹⁴ A recent study by an industry analyst concluded: "Initially, Apple with its iOS dominated the U.S. tablet PCs market; however, Android based tablet PCs are expected to take over Apple's share in the coming years."¹¹⁵ Except for portable digital media players, the experience in consumer electronics during the new millennium is that consumers prefer choice – to mix complementary products from different vendors.

In the relevant markets in this case, the only other firm that tried to construct a "walled garden" of products that were incompatible with all other products was Microsoft with Zune. The first Zune, released in 2006, received mixed reviews, but the second

smartphone-market-share/ (reporting sales data from Gartner).

113. Chuck Jones, "Samsung Dominates Android Devices," *Forbes*, February 7, 2013, at <http://www.forbes.com/sites/chuckjones/2013/02/07/samsung-dominates-android-devices/> (reporting data from Localytics).

114. Shane Richmond, "Apple iPad Market Share Falls as Tablet Market Booms," *The Telegraph*, January 31, 2012, at <http://www.telegraph.co.uk/technology/apple/9839631/Apple-iPad-market-share-falls-as-tablet-market-booms.html> (reporting NPD data for the fourth quarter of 2012). See also Nikhil Subramaniam, "Apple's Tablet Market Share for Q4 Falls in Face of Samsung Surge," *Tech2*, February 2, 2013, at <http://tech2.in.com/news/tablets/apples-tablet-market-share-for-q4-falls-in-face-of-samsung-surge/733692> (reporting sales data from IDC for 2012).

115. Press release from Research and Markets, reported as "Research and Markets: Tablet PC Market – U.S. Industry Analysis, Size, Share, Growth and Forecast, 2012-2018," *Yahoo Finance*, February 5, 2013, at <http://finance.yahoo.com/news/research-markets-tablet-pc-market-161100545.html>.

release, in 2007, was received very favorably. The CNet review stated:¹¹⁶

“Having survived its freshman hazing, the Zune is back for its sophomore revenge, and the iPod has every reason to be frightened. With a new design, higher capacity, wireless sync capability, larger screen, and integrated support for audio and video podcasts, the new 80GB Zune (\$249) is finally giving everyone a true alternative to the iPod.”

The CNet editors gave the Zune the same rating (four stars, excellent) as the iPod Touch. But consumers rejected Microsoft’s product. The Zune never achieved significant market share, and eventually was withdrawn from the market.

The experiences with consumer electronics over the last decade do not support the conclusion that integrated systems are better. When consumers are given the choice, most prefer products that do not lock them in to a single vendor for multiple products.

DAMAGES

In antitrust economics, damages are calculated by comparing actual prices for the reference product with prices that would have been charged in the “but-for” world in which the alleged anticompetitive acts had not occurred. A damage analysis estimates prices in a hypothetical more competitive market – the “competitive benchmark” – that would have been present had there been no anticompetitive conduct.¹¹⁷

In analyzing damages in this matter, the task is to calculate the extent to which the alleged anticompetitive conduct enabled the defendant to set higher prices for iPods than

116. “Microsoft Zune,” *CNet*, November 7, 2007, at http://reviews.cnet.com/mp3-players/microsoft-zune-second-generation/4505-6490_7-32638989.html.

117. In their text Professors Kip Viscusi, Joseph Harrington and John Vernon state the general principle: “Standard antitrust practice is to calculate damages... as the additional revenue on the units sold.” W. Kip Viscusi, Joseph E. Harrington, Jr., and John M. Vernon, *Economics of Regulation and Antitrust*, 4th Edition, MIT Press, 2005, p. 145.

otherwise would have been charged if the market for portable digital media players had been more competitive. The competitive benchmark is not necessarily an intensely competitive market. Instead, it represents the degree of competition that would have been present had the anticompetitive acts not occurred, which in some circumstances is an oligopoly. Thus, a valid damage analysis must take into account that in the absence of anticompetitive conduct, Apple would have enjoyed some market power in iPods.

General Considerations in Estimating Damages

The class in this matter includes both end-users and intermediaries who bought iPods from the defendant. These two types of customers paid different prices. Consumers paid retail prices from the online or traditional retail outlets of the Apple Store, while wholesale distributors and large retail competitors of the Apple Store paid reseller prices from Apple's wholesale distribution operation. Consequently, the method for calculating damages should take into account whether the product was sold at retail or wholesale. If markets are competitive, the wholesale and retail prices of a firm that operates in both markets differ according to the firm's sales costs in the two distribution channels; however, a firm that enjoys market power in manufacturing may have the power to engage in effective price discrimination among categories of buyers. If so, the amount of damages per unit sold will differ between retail and wholesale buyers.

Methods of Damage Estimation

Economists use three basic approaches to establishing competitive benchmark

prices: “before-after,” “yardstick,” and “mark-up.”¹¹⁸ My experience in other class action litigation provides further evidence that these methods are standard within the economics profession and in antitrust litigation. I have successfully proposed one or more of these methods for calculating damages in several class action antitrust cases dealing with many different types of products: luxury tableware,¹¹⁹ dynamic random access memory (DRAM),¹²⁰ static random access memory (SRAM),¹²¹ compact discs,¹²²

118. These approaches are described and widely accepted in scholarly writings in antitrust economics. Professors Roger Blair and David Kaserman devote a section of their text to damages calculation. They summarize the standard approaches in antitrust economics by stating that “the measure of damage is roughly equal to the wealth transferred to the monopolist from the buyers.” Roger D. Blair and David L. Kaserman, *Antitrust Economics*, Richard D. Irwin, 1985, p. 78. They list “three basic theories or how one goes about measuring... overcharges” as the “before and after theory,” the “yardstick theory,” and the “market share theory.” *Ibid.*, pp. 78-79. (The last is only relevant to estimating the lost profits of a competitor that is harmed by anticompetitive conduct, so is not pertinent here.) The “yardstick approach to damage estimation is based upon a comparison of the plaintiff’s experience with that of a firm or market that was unaffected by the illegal activity... A plaintiff that is claiming damage due to overcharges may attempt to compare the prices it paid with those charged in similar markets where there was no antitrust violation.” The before-after and yardstick methods are described in John Johnson, “Economic Approaches to Antitrust Damage Estimation,” National Economic Research Associates, January 2005. All three methods (with the mark-up approach separated into three ways that it can be implemented) are discussed in John M. Connor, “Forensic Economics: An Introduction with Special Emphasis on Price Fixing,” *Journal of Competition Law and Economics*, Vol. 4, No. 1 (March 2008), pp. 31-59. According to Professor Connor: “The principal challenge for forensic economists is to calculate the relative competitive benchmark price...” *Ibid.*, p. 45. He then goes on to describe the principal methods of calculating damages as the “before and after method” (which he dates to the 1920s), the “yardstick method” (which he notes has been used in cases involving bread, milk and construction services), the “cost-based approach,” the “constant-margin approach” (which was used in the Vitamin E conspiracy), and the game theory method. *Ibid.*, pp. 46-53. His yardstick approach is the same method that I call the yardstick method, and his constant-margin and game-theory approaches are the methods that I call the mark-up test.

119. *In Re Tableware Antitrust Litigation*, U.S. District Court, San Francisco, California.

120. *In Re: DRAM Antitrust Litigation*, U.S. District Court, San Francisco, California.

and repair and maintenance of high-speed photocopiers¹²³ and body imaging devices.¹²⁴

After having examined the data and the other evidence in this litigation, I have decided that the best method for calculating damages as well as proving anticompetitive impact is the “before-after” method. The “before-after” method compares prices of the reference products (here, iPods) before and/or after the occurrence of the anticompetitive acts with prices during the damage period. I have implemented this method by estimating an econometric model of price formulation for iPods.

The basic approach that I have adopted starts with a hedonic model of iPod prices that takes into account the fact that Apple sells many models of iPods with different features. In a hedonic equation, price is expressed as a function of the qualitative attributes of the product.¹²⁵ The qualitative attributes that are included in the regressions are indicator variables for each product class (classic, mini, nano, shuffle, touch), an indicator variable for the U2 special editions, the logarithm of time measured as the number of months between the current month and the month in which the iPod was introduced (2001) (to represent technical change not captured in other variables),

121. *In Re: Static Random Access Memory (SRAM) Litigation*, U.S. District Court, San Francisco.

122. *Consolidated Compact Disc Antitrust Litigation*, U.S. District Court, Los Angeles, California.

123. *R&D Business Systems v. Xerox*, U.S. District Court, Marshall, Texas.

124. *Southeast Georgia Regional Medical Center vs. General Electric Corporation*, U.S. District Court, Brunswick, Georgia.

125. The hedonic model that I have estimated is similar to a model that was used to estimate a price equation for mobile telephones. See Ralf Dewenter, Justus Haucap, Ricardo Luther, and Peter Rotzel, “Hedonic Prices in the German Market for Mobile Phones,” *Information Economics and Policy* 31 (2007), pp. 4-13.

files. The coefficients on these indicator variables quantify the competitive effects of changes in the extent of compatibility between iPods and competing download sites.

Apple introduced the first iPod in 2001. While the initial versions of the iPod were successful, the iPod was not dominant in the market for portable digital media players. The initial event that caused Apple to obtain monopoly power in both audio downloads and portable digital media players was the launch of iTunes along with an iPod that was the only portable digital media players that could play audio recordings in the FairPlay DRM system. These products were launched in April 2003. The initial period before iTunes was created and the period after the launch of iTunes establish the “before” period for measuring Apple’s market power prior to the events surrounding the release of Harmony, the attempts to disable Harmony, and the movement to DRM-free files. This procedure provides a separate estimate of the price effect of each event that changed competitive conditions in the market for iPods.

Two important events occurred in October 2003. First, iTunes became accessible on Windows-based personal computers, and second, the major record labels licensed competing web sites to sell audio downloads with DRM protection. During a transition period between October 2003 and February 2004, several Internet sites – including Napster, RMS and WalMart – became fully operational as competitors to iTunes. By March 2004, iTunes had several competitors in audio downloads. The effect of iTunes on iPod prices is captured by an indicator variable that takes the value of one after iTunes is launched and is zero for the period before that date.

Harmony was introduced in July 2004. Harmony enabled many brands of portable digital media players, including iPods, to be compatible with the RealNetworks

audio download service. Harmony converted files that used the RealNetworks Helix DRM protection into either the protected WMA or FairPlay format for use on an otherwise incompatible portable digital media player. The important aspect of Harmony for purposes of damage estimation is that it enabled iPod users to download audio files from a site other than iTunes. Harmony was operational until Apple's software upgrade of October 2004, iTunes 4.7. RealNetworks apparently made another attempt in 2005 to restore Harmony's compatibility with iPods, but Harmony again was made incompatible with iPods with the iTunes 7.0 update in September 2006. RealNetworks never overcame the incompatibility created by iTunes 7.0.

The indicator variable for Harmony takes the value of one for all periods after Harmony was launched. This procedure is followed for two reasons. First, the iTunes 7.0 update applied only to new iPods. Harmony continued to work on old iPods, which meant that consumers who had used Harmony on old iPods continued to be able to do so, which would have affected the extent to which they were locked in to iPods. Second, this procedure permits separating the positive competitive effect of Harmony from the negative competitive effect of disabling it after iTunes 7.0 was released. If the Harmony variable were zero during the periods that it was disabled by iTunes 4.7 and iTunes 7.0, the coefficients on the latter variables would be the net effect of those events under the assumption that Harmony did not exist. To separate the effect of these updates from the effect of Harmony requires setting the Harmony variable to one for the entire data period after its launch.

Between October 2004 and April 2005, and then again from September 2006 on, updates to the Apple DRM system made Harmony incompatible with new iPods.

Indicator variables for the period in which iTunes 4.7 and iTunes 7.0 made Harmony incompatible with iPods also are included in the model. Between May 2007 and March 2009 legal audio download sites made a gradual transition to DRM-free audio recordings. EMI allowed DRM-free downloads in April 2007, and iTunes began selling EMI audio downloads without DRM protection in May 2007. Competitors to iTunes began selling some DRM-free downloads from EMI and Universal in August 2007. All four other major record companies allowed Apple's competitors to sell a complete digital repertoire of DRM-free downloads by January 2008, and by March 2008 this change in policy had been fully implemented. By January 2009, all major record companies had agreed to let iTunes sell DRM-free downloads, which was fully implemented on April 1, 2009. Competing audio download sites had an advantage compared to iTunes until iTunes began to provide complete DRM-free downloads. Separate indicator variables are used for the full implementation of DRM-free audio files by competitors and by iTunes.

The periods for the various indicator variables that measure potential competitive effects are: pre-iTunes (November 3, 2001 to April 27, 2003); post-iTunes (from April 28, 2003 to the end of the period for which Apple has produced transactions data); Harmony available (beginning July 26, 2004 to the end of the data period); Harmony disabled with update 4.7 (beginning October 26, 2004 and ending September 11, 2006 when update 7.0 was released); update 7.0 (beginning September 12, 2006 and running to the end of the data period); iTunes competitors fully DRM-free (beginning January 1, 2008 and running to the end of the data period); and iTunes fully DRM-free (beginning March 31, 2009 and running to the end of the data period). The pre-iTunes period is the omitted category.

In addition to events affecting competition in the market, other factors also could

affect the price of iPods. The demand for iPods is likely to depend on the availability of digital downloads, so that one factor affecting price changes for iPods over time may be the number of permanent downloads that are available on iTunes. Moreover, digital media players, like all electronics products, experience rapid technological progress. To take technology into account, economists frequently use a time trend as well as a measure of unit cost. [REDACTED]

[REDACTED]

The specification that I have concluded produces the most reliable estimate of damages is to regress the logarithm of price on indicator variables plus the logarithm of variables that are continuous; however, I also have estimated the linear specification. I have estimated separate equations for the two types of class members, resellers (wholesale customers) and direct purchasers (retail customers). [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] In the preferred regression I have eliminated the outlier observations; however, I have also estimated the regressions with the outlier observations included. Finally, to avoid bias in coefficient estimates arising from the fact that the data set contains a very large number of very small purchases, I have weighted each observation by the quantity sold.

The two preferred regressions (logarithmic equations with outliers removed) are reported in Exhibit 13; the other regressions (logarithmic equations with outliers included, and linear equations with and without outliers) are contained in Appendix C. The linear specifications produce higher estimated damages, but I believe that they are

less reliable. The other logarithmic equations produce results that are close to the results of the preferred equations.

The calculations of damages from these regressions are reported in Exhibits 14 through 16. The method for calculating damages for each type of buyer is to multiply the percentage mark-up during the iTunes 7.0 period times the average transaction price for each model, defined by a class, generation and family as they appear in Apple's data base. The disaggregated damages are then aggregated to a class and generation, then to just a class, and then to a total for each type of buyer. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Exhibit 15 disaggregates damages to the level of class and generation, while Exhibit 16 further disaggregates damages to the level of class, generation and family.

Reseller Price Regression

This section reports the results of the price regression on the current version of Apple's reseller transactions data. The reseller transactions data cover the period from November 3, 2001, through March 26, 2011. Each record refers to a shipment to a reseller. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Because of the remaining problems and unanswered questions about the transactions data, many records were eliminated

observations of this variable were for very few units, the quantity variable was converted into ranges: an indicator variable for sales of 1 to 5 units, and indicators for whether remaining quantities were low, medium or high. The “low” group is the omitted category. This variable captures the possibility that some discounts are more available to, or are larger for, high-volume purchasers.

[REDACTED]

The coefficient on each of these indicator variables is the permanent price effect of that event to the end of the data period, with the exception of the 4.7 indicator which measures the price effect from the release of update 4.7 until the release of update 7.0.

Exhibit 13.1 shows the results of the preferred logarithmic regression analysis on reseller transaction data.¹²⁷ The overall power of the regression is measured by “adjusted R^2 ,” which is the fraction of the variation in the dependent variable (here, price) that is explained by the estimated equation, taking into account the number of parameters that are estimated.¹²⁸ An adjusted R^2 of 1.0 indicates that the equation completely explains all

127. The equation also has been estimated with adjustments for heteroskedasticity and the results are the same using heteroskedasticity-consistent standard errors.

128. A property of regression analysis is that by adding more explanatory variables, one normally can explain more variance in the dependent variable, even if there is no causal

variation in the dependent variable, and an adjusted R^2 of 0.0 indicates that the equation explains nothing. The values of the adjusted R^2 for this regression is 0.9866, which means that virtually all of the variation in prices across models of iPods and among time periods is explained by these equations.

Another test of the quality of a regression is whether the estimated coefficients are consistent with expectations derived from economic theory. For example, prices for consumer electronics generally fall through time due to the presence of ubiquitous learning-by-doing and Moore's Law. The positive coefficient on the logarithm of time bears out this expectation. [REDACTED]

[REDACTED]

[REDACTED]

One result of interest is the coefficient on unit cost, which is positive and highly significant in all specifications. While this result shows substantial cost pass-through, the pass-through rate also is substantially less than one. This result is consistent with the research publications cited elsewhere that Apple engages in price discrimination among products, which is another indicator of the presence of market power.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

relationship between the dependent variable and the additional explanatory variables. The version of R^2 that is reported here takes this phenomenon into account, and so is a more accurate measure of the explanatory power of the regression than unadjusted R^2 .

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

Damages are calculated by multiplying the percentage increase in price due to the iTunes 7.0 update, which is calculated from the coefficient on the iTunes 7.0 variable, by the price of each class/family/generation of iPod. Exhibit 14 shows the average damage per unit sold and the total amount of damages to resellers for the entire class period. Exhibit 15.1 disaggregates the reseller damages to a class and generation of iPod, and Exhibit 16.1 further disaggregates the reseller damages to a class/generation/family.

Direct Sales Regressions

The direct sales transaction data cover the period from November 2001 through December 2011. Each record has a line item on an invoice of a direct purchase of an iPod. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] The price is calculated by dividing the “amount” variable by the “quantity” variable of that particular line item on the invoice.

[REDACTED]

[REDACTED]

Major Data Issues

[REDACTED]

Apple has not provided sufficient information to link all returns and exchanges to the original sales. As a result the data that were used in the regressions may have some double counting. For example, a customer might order an iPod online, then return it to an Apple store to exchange it for another color or to trade in the initial model for another model at a different price.

Returns data are important because they imply that a prior transaction should be eliminated or, if the return is a trade-in, adjusted. The transactions data contain some information about returns, but Apple has not provided sufficient information to identify all returns and exchanges. Ideally, if Apple had provided complete information, cleaning the data would have involved identifying price-related adjustments to all sales. For returns for credit, the entire transaction could be removed from the data. For adjustments to original sales, the true transaction price could be calculated from the set of records involving the same sale.

[REDACTED]

[REDACTED]

Just two weeks before my expert report was due, Apple provided a “returns.zip” file with eleven compressed text files that supposedly contain the cross reference between

130. SFI_808637_2_Responses to Price Override Questions.pdf

the original sale and subsequent returns. Apple provided no dictionary for the variables in the data. The text files contain an invoice identifier and original invoice identifier, but these files provide neither an invoice item number that can be used to match exactly with a record in the transactions data nor the original invoice item number that would also allow a match with the original sales data. This was the first time Apple produced data that included the original invoice identifier, making clear that documents Apple had provided previously lacked a key linkage variable.

In response to Plaintiff's request for clarification, Apple provided vague and inaccurate answers and sent another file, "PD2_Invoice_Xref_CreditsDebitsReturns.zip," which contains a similar linkage for online sales. This file contains a different set of variables, but does include an invoice identifier and item number as well as the corresponding original invoice identifier and original item number information.

The newly produced data files were used to attempt to match returns and adjustments with their corresponding original sales. The "returns.zip" file (also known as PD3 for retail sales) contains 2,880,937 records and 11 variables, of which six were not provided previously. The five variables that may be used to match with the original file are invoice identifier, product identification, billing quantity, billing amount, and original invoice identifier. When comparing specific records, the billing amount in this new file did not match the billing amount contained in the original direct sales file. The likely difference between PD3's billing amount and the billing amount in the transactions data is a restocking fee. Without further explanation from Apple, a proper investigation of this possibility was not feasible in the few days between the receipt of the data and the deadline for the report.

Various combinations of variables were used to attempt to match the new data to the original transaction data, but Apple did not provide a set of variables to use as unique identifiers with which to accurately create one-to-one matches between data sets.¹³¹

[REDACTED]

Apple's solution to problems with PD3 records is as follows: [REDACTED]

[REDACTED]

[REDACTED]¹³²

Had Apple sent these files earlier in response to previous requests, perhaps some returns could have been linked to the original sales; however, given the extraordinarily large size of the data set, this could not be accomplished in the few days that were available before the report deadline. Thus, all records that may be linked to a return,

131 [REDACTED]

132. Apple's answers to the "Additional Questions for Apple Regarding Matching of Direct Sales and Returns," SFI-819714v.1.

credit or any adjustments using Apple's cross reference files were deleted from the regression analysis to minimize biases that may be introduced by including inaccurate prices. This procedure also is likely to cause damages to be underestimated because potentially legitimate sales have been excluded from the calculations. [REDACTED]

[REDACTED] If more information were available, some of these records are likely to have been identified as legitimate and included in the analysis.

The most important variables in the regression are the indicator variables for competitive conditions, especially for iTunes 7.0. For an indicator variable to include the correct transactions, the date of purchase must be accurately recorded. The direct sales data contain two dates, the shipment date and the billed date. Because only online sales have a shipment date, billed date is used for purposes of determining the date of the sale.

Another key variable in the econometric model is price, which is calculated by dividing the amount variable by the quantity variable if the value of the quantity variable is not equal to zero. The goal is to calculate a price that Apple charged for an iPod in a given transaction. Prices should exclude other costs, such as taxes and delivery charges. If a price adjustment is made for customer dissatisfaction due to late delivery, the adjustment is not related to the iPod purchase price. But some post-sale promotions and price adjustments change the actual price paid. To calculate accurate prices, the transaction amount must be accurate, and so must include returns, credits, and adjustments that were applied to the original transaction.

[REDACTED]

Direct Sales Regression

This section reports the results of the price regression on the current version of Apple's direct sales transactions data. For each transaction, a set of quantity indicator variables were created based on the total quantity being purchased. The categories are: Greater than 5, greater than 10, greater than 20, greater than 50 and greater than 100. Thus, the price effect of a particular size of transaction is measured by the sum of the coefficients of all quantity ranges up to that amount.

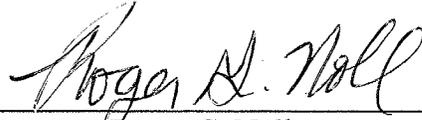
Exhibit 13.2 shows the results of the preferred regression.¹³³ The values of the adjusted R^2 for the preferred regression is 0.9813 which means that virtually all of the variation in prices across models of iPods and among time periods is explained by these equations. Exhibit 14 shows the average damage per unit sold and the total amount of damages to direct purchasers. Exhibit 15.2 disaggregates the damages to direct purchasers to a class and generation of iPod, and Exhibit 16.2 further disaggregates the damages to direct purchasers to class/generation/family.

[REDACTED]

The coefficient on unit cost is positive and highly significant, indicating substantial cost pass-through. But the results also indicate that much of the price differences among iPod models are explained by model features, indicating substantial price discrimination.

133. The equation also has been estimated with adjustments for heteroskedasticity and the results are the same using heteroskedasticity-consistent standard errors.

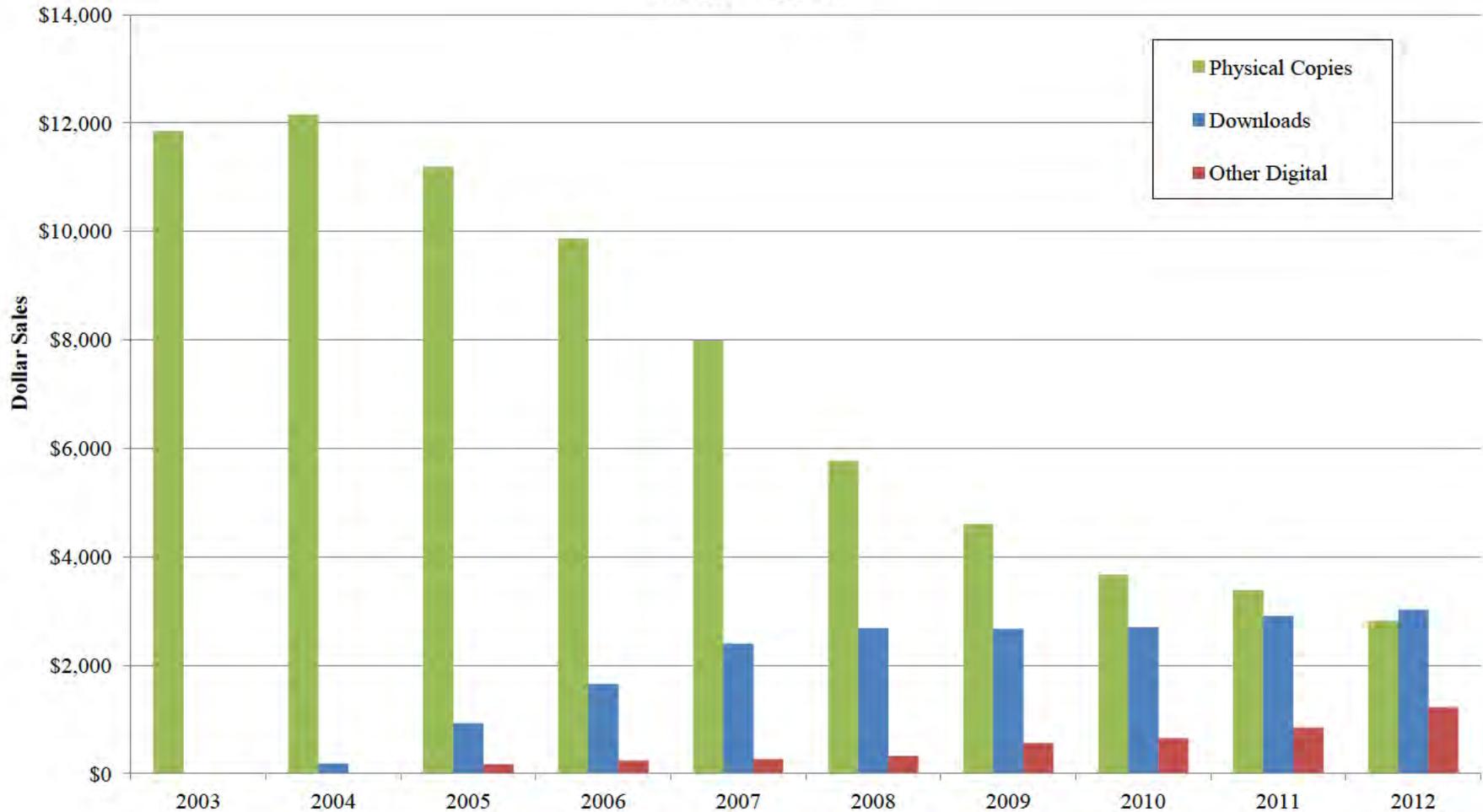
I declare that the foregoing is true to the best of my knowledge and belief.

A handwritten signature in cursive script, appearing to read "Roger G. Noll", written in black ink.

Roger G. Noll

Executed at Stanford, California, April 3, 2013.

Exhibit 1 Music Sales Millions of Dollars 2003 - 2012

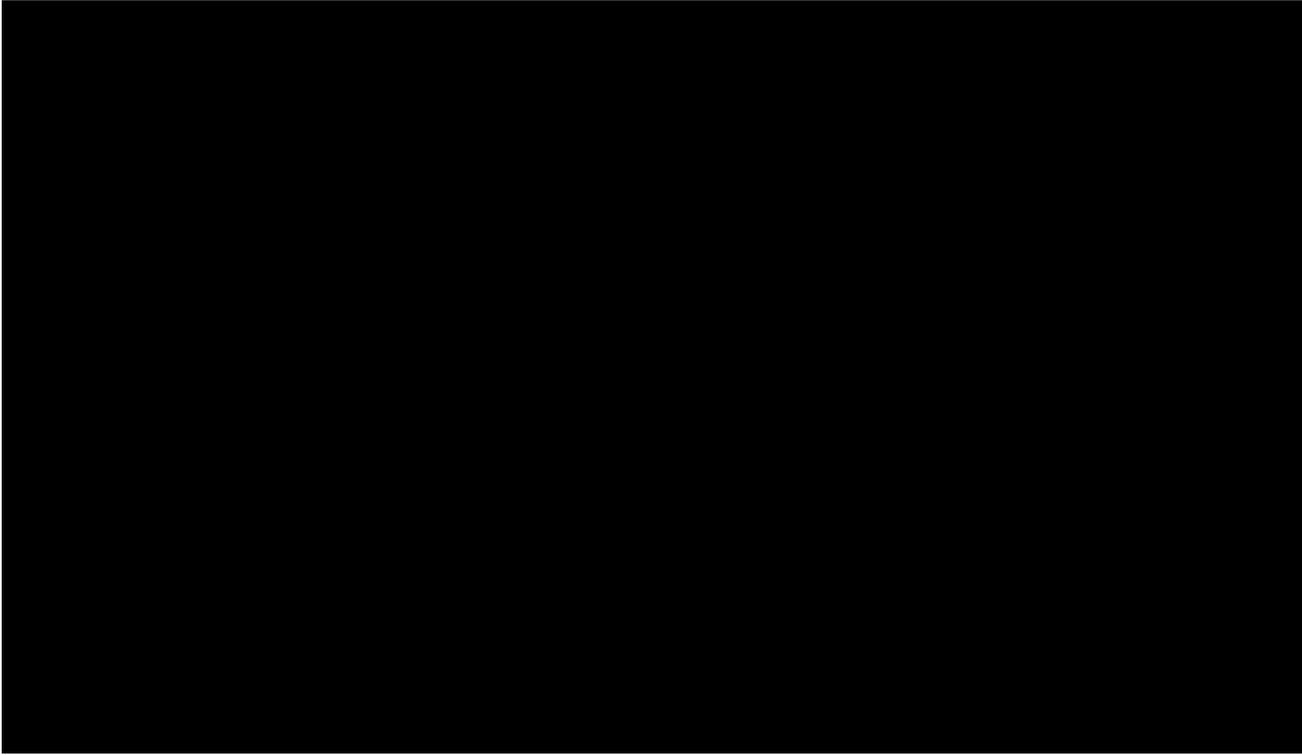


Notes:

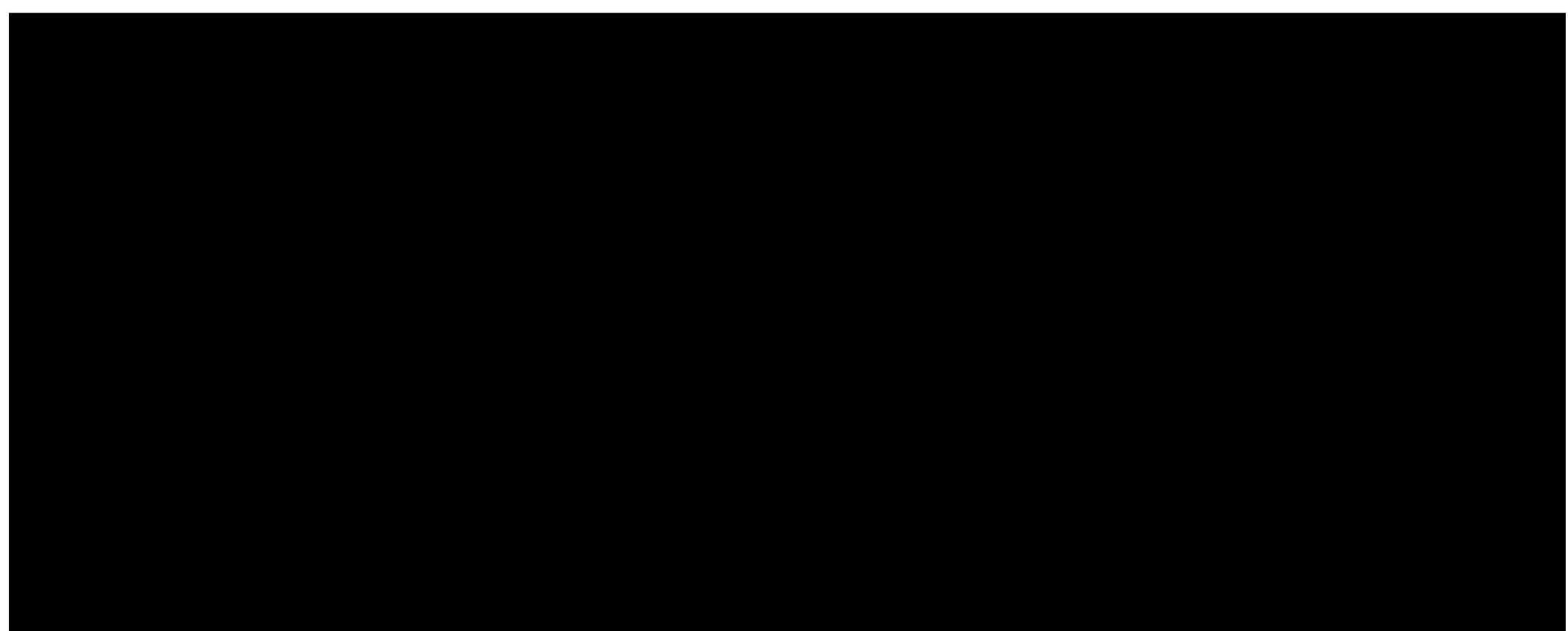
- 1) Downloads includes Download Album, Download Single, Download Music Video, Kiosk, and Mobile.
- 2) Other Digital includes Subscription & Streaming Not Distributed by SoundExchange, SoundExchange Distributions, and Synchronization.
- 3) Physical Copies include 8 - Track, Cassette, Cassette Single, CD, CD Single, DVD Audio, LP/EP, Music Video, Other Tapes, SACD, and Vinyl Single.

Source: RIAA Year End Industry Shipment and Revenue Statistics, http://www.riaa.com/keystatistics.php?content_selector=research-shipment-database-overview.

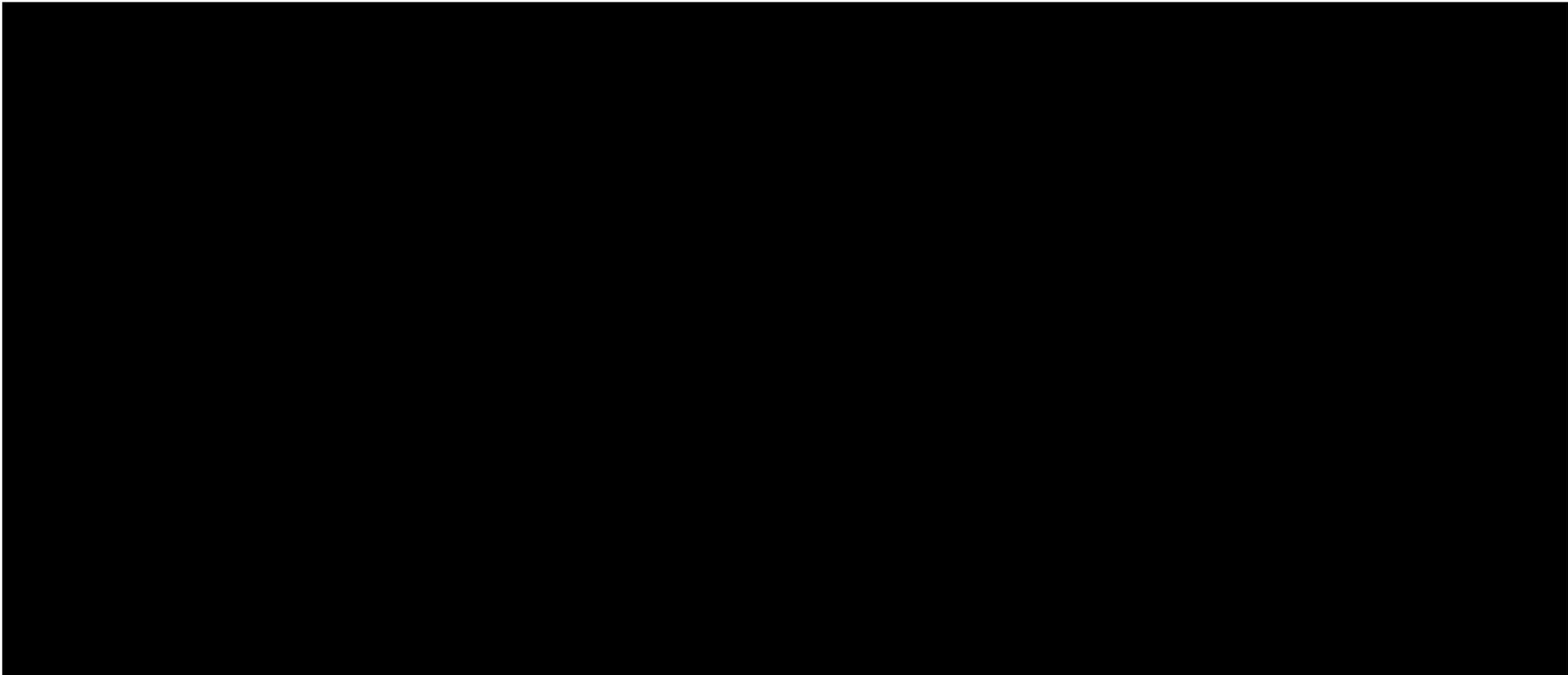




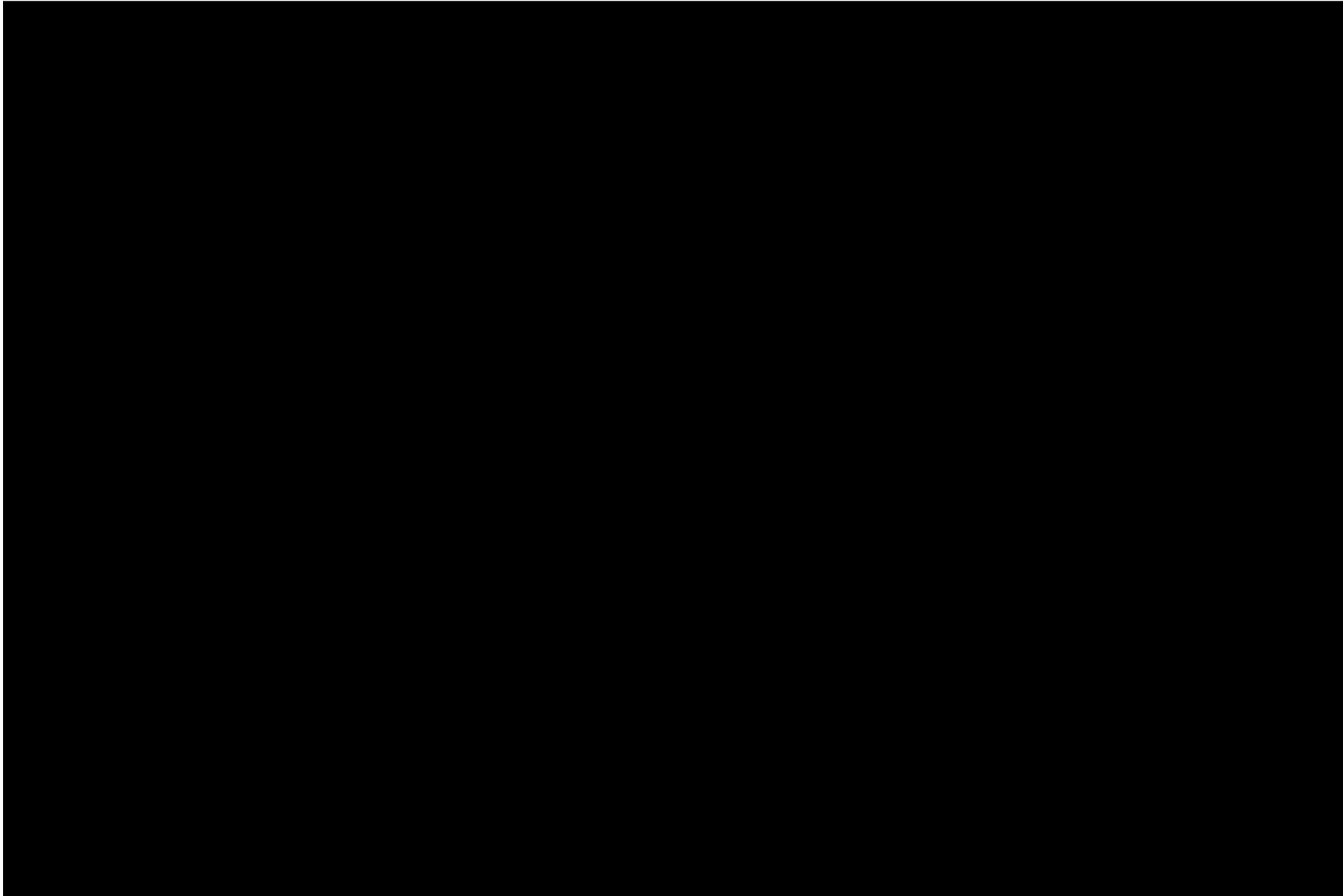


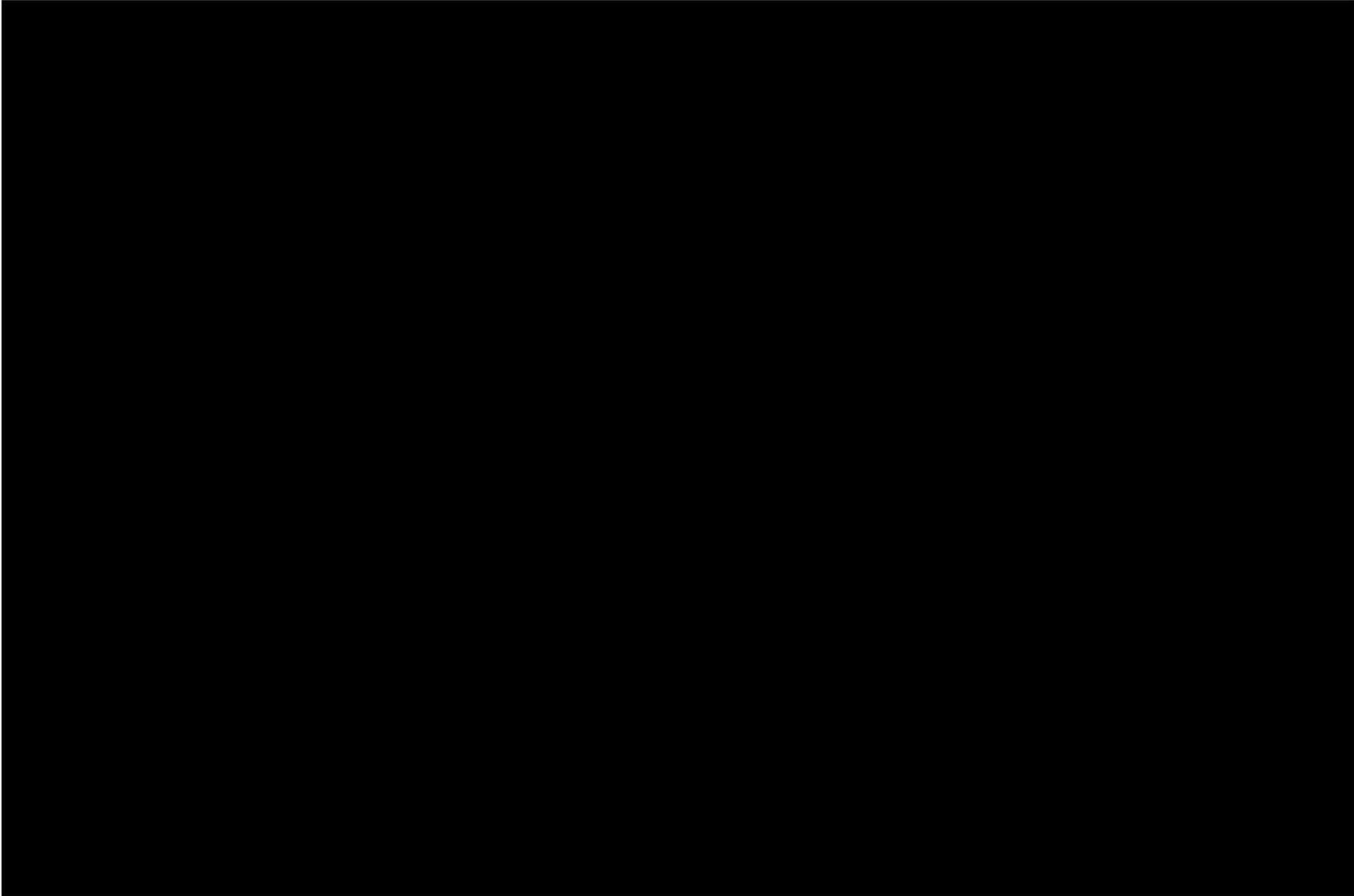


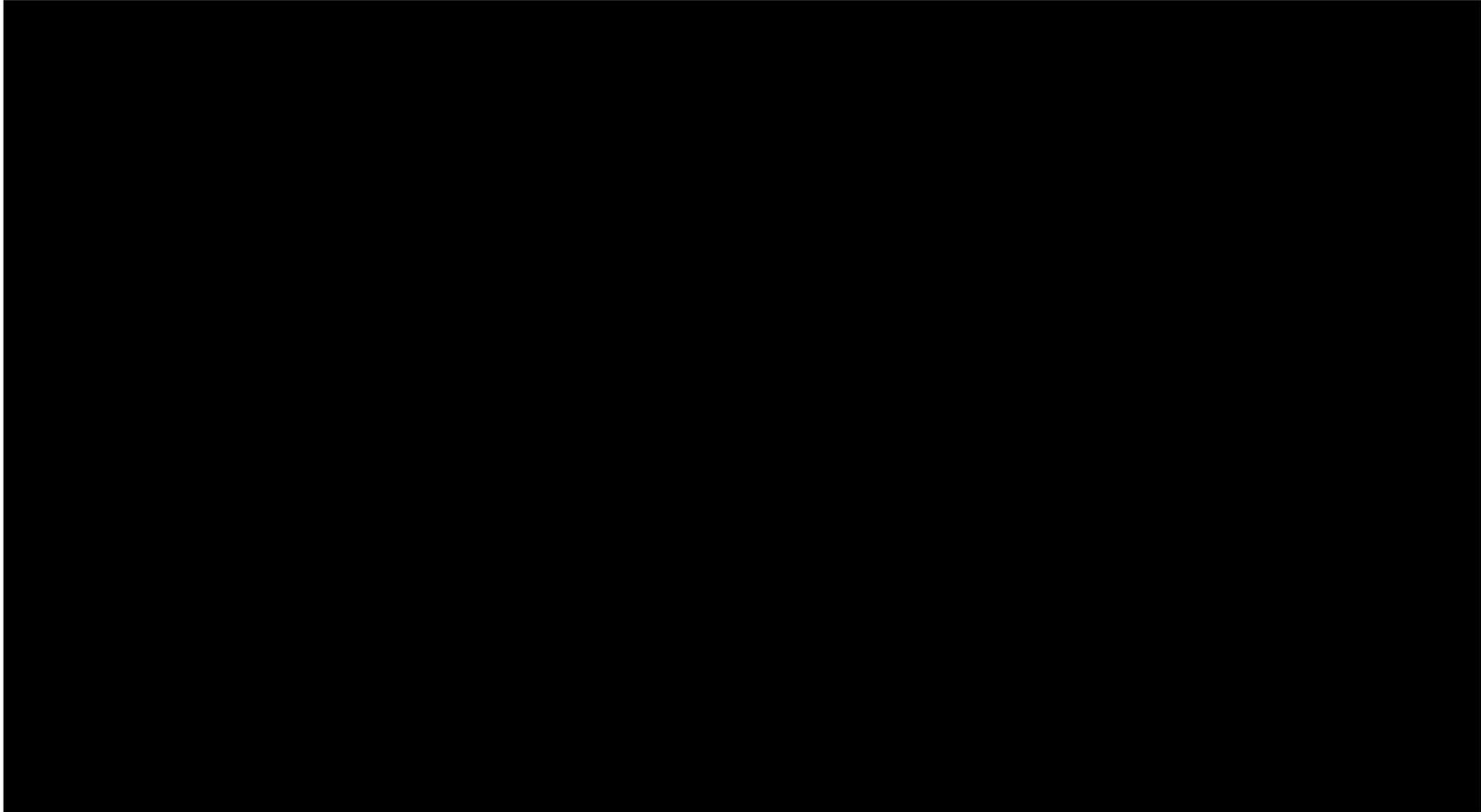
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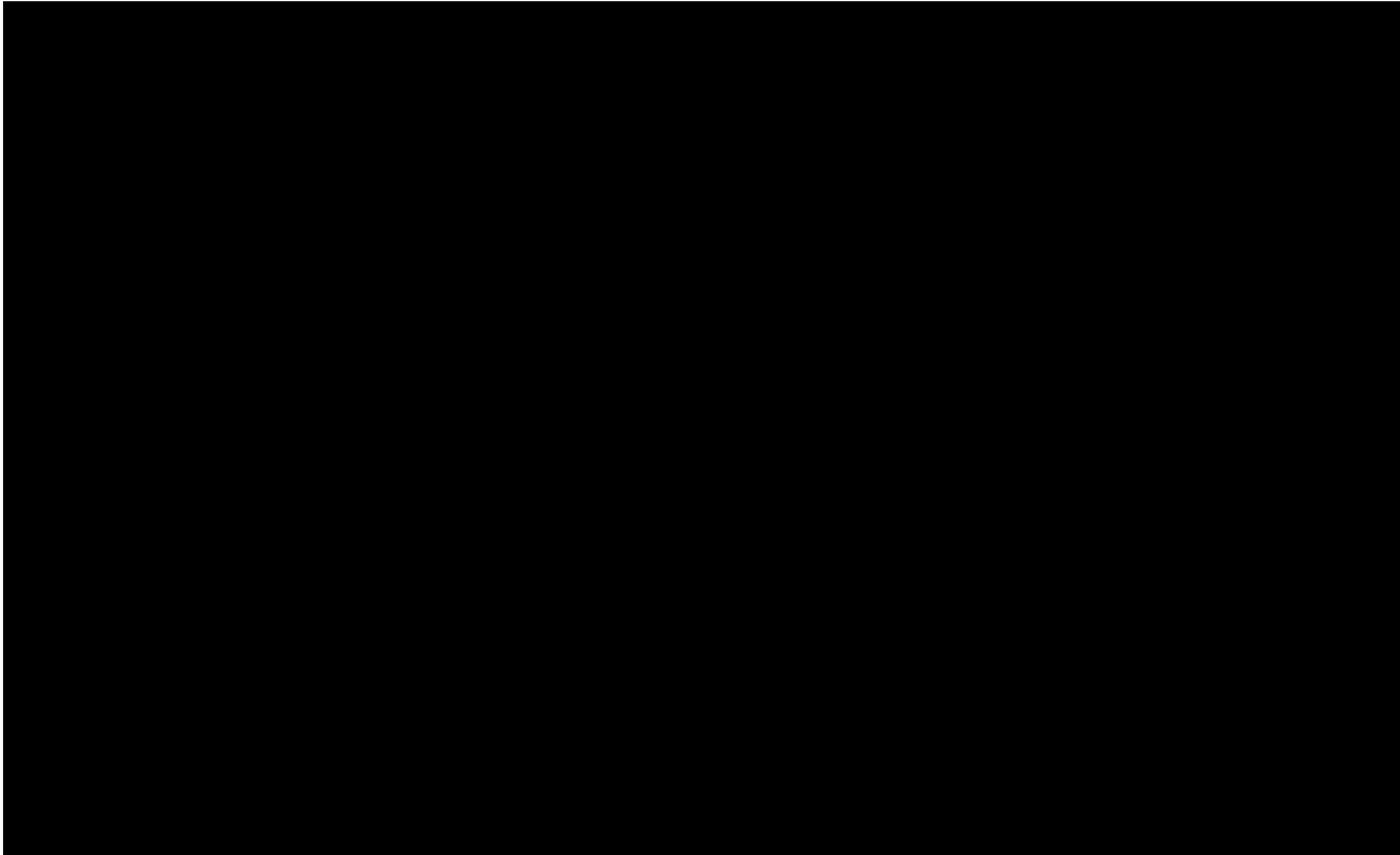


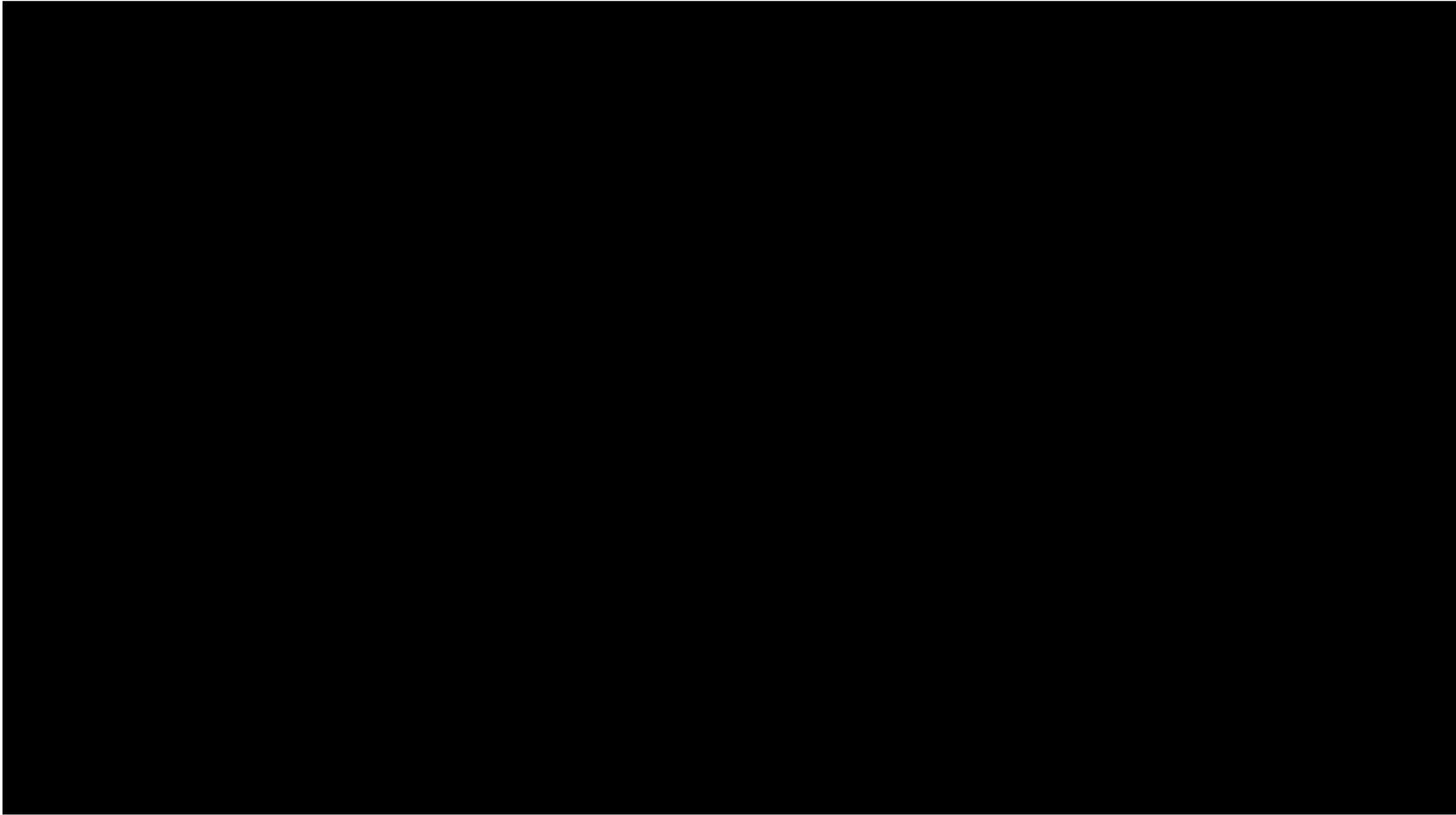
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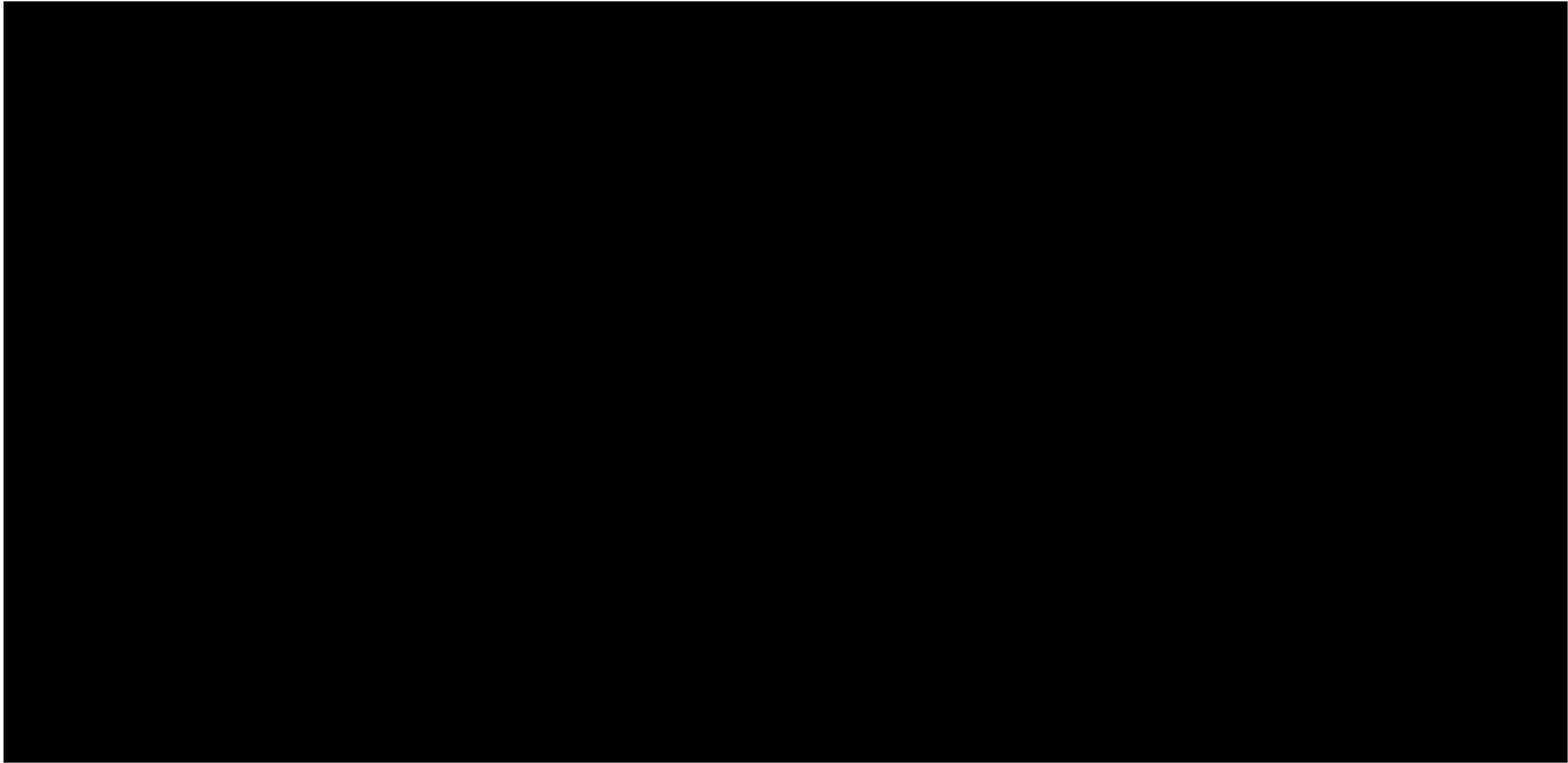


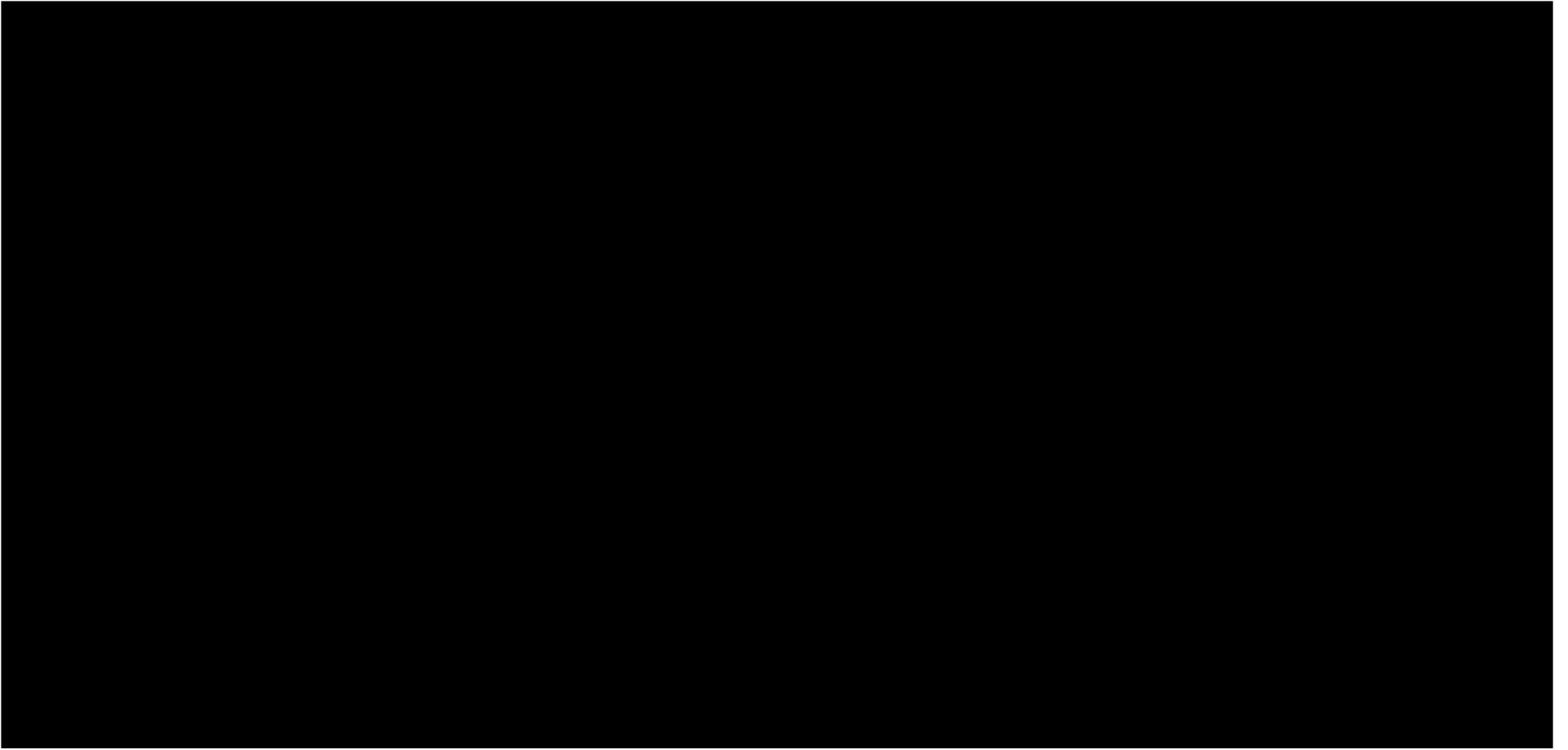


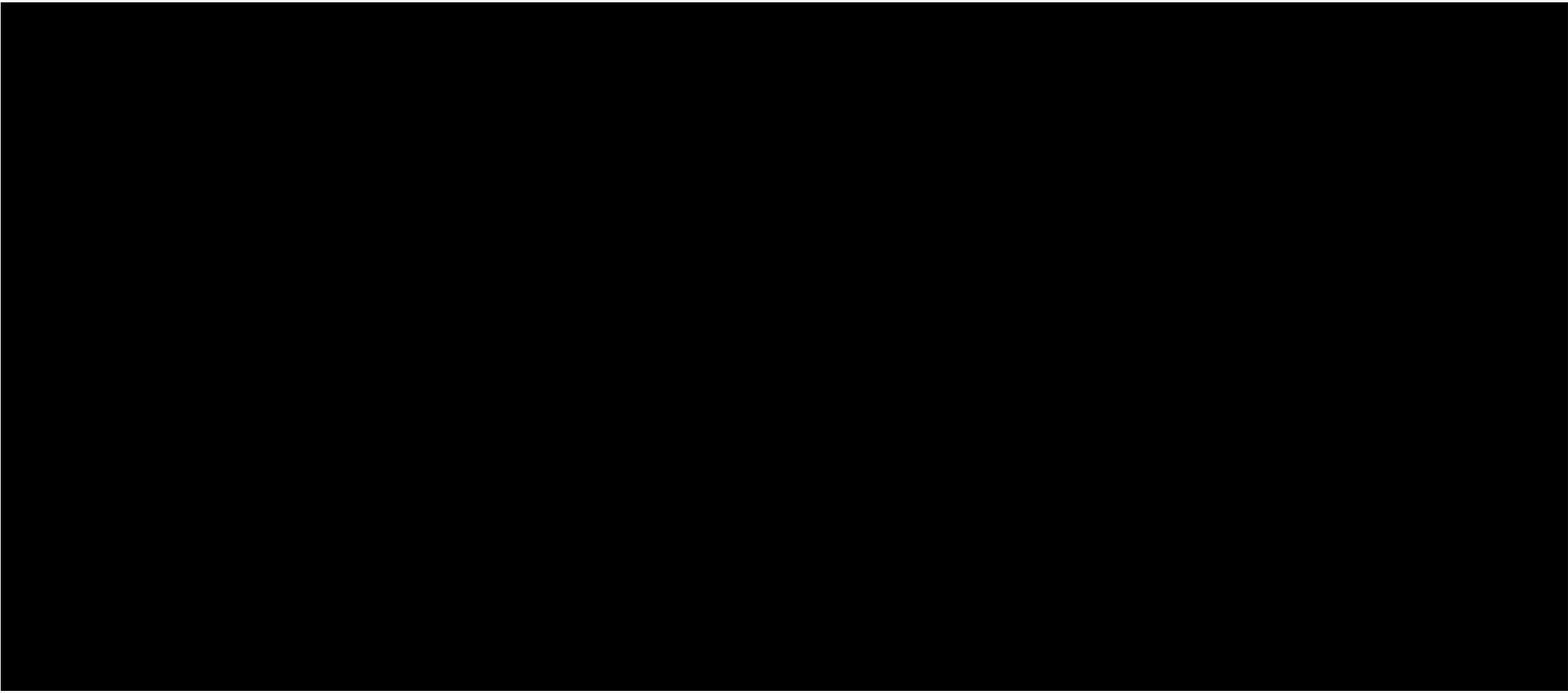


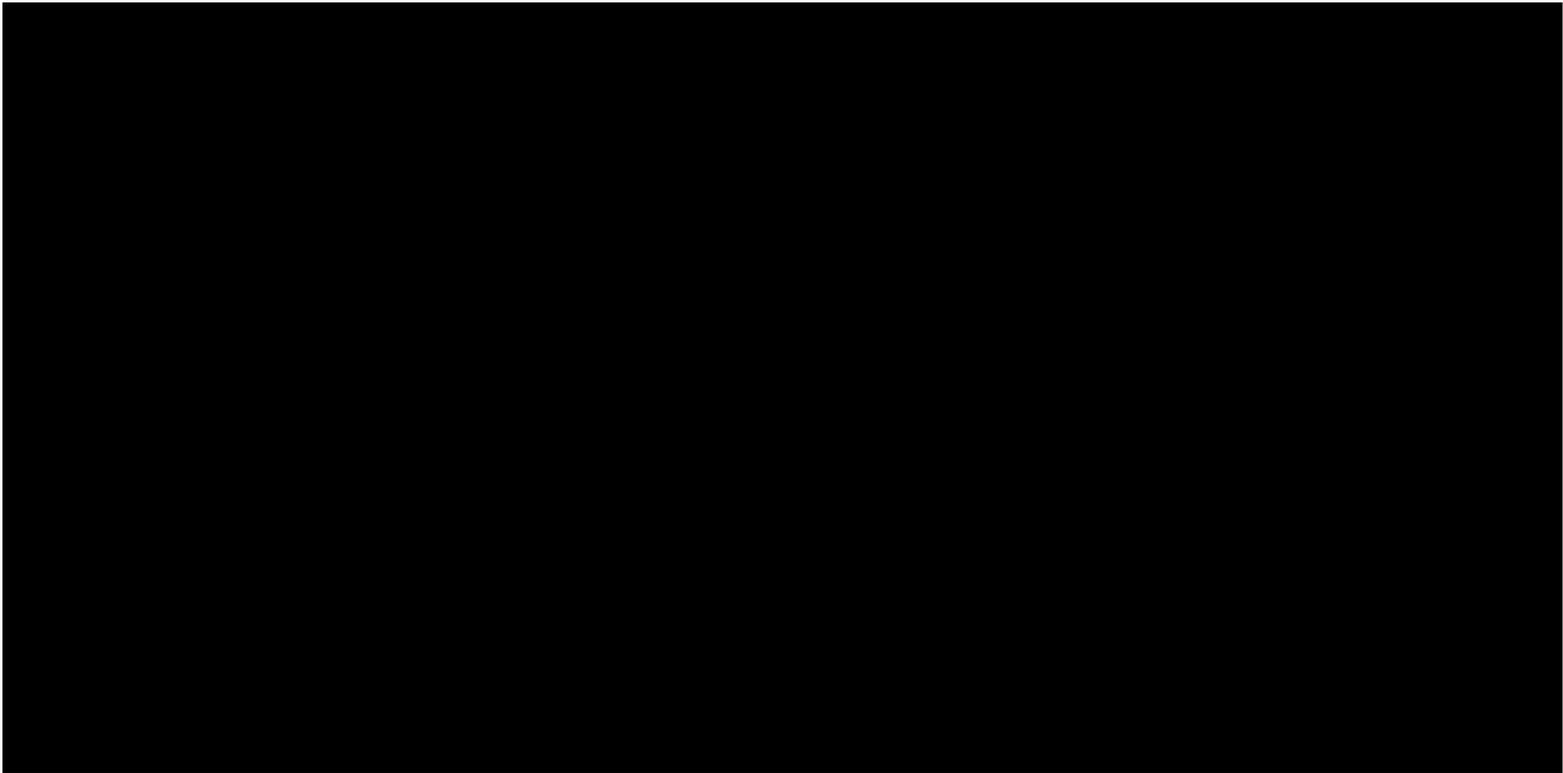


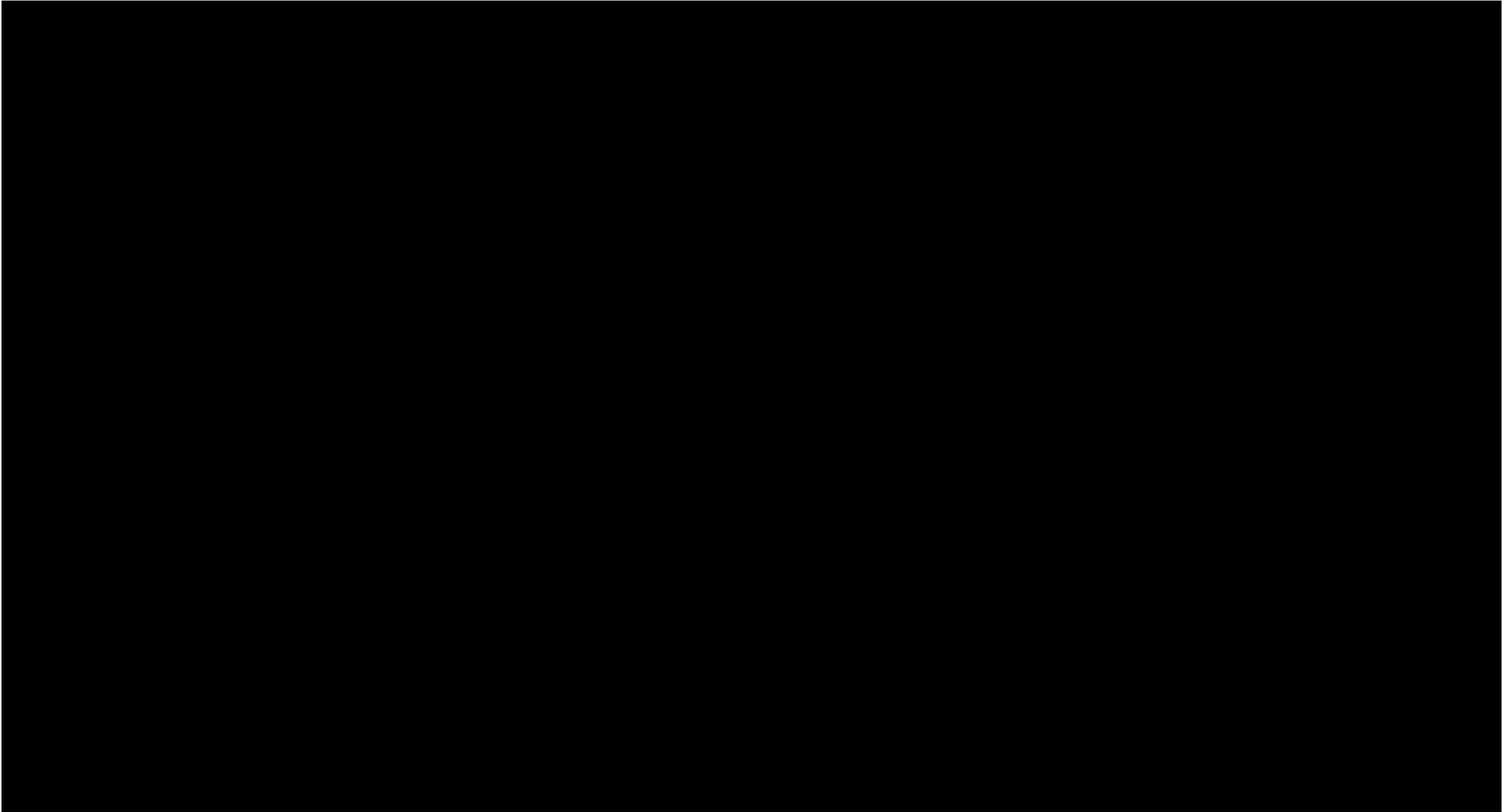






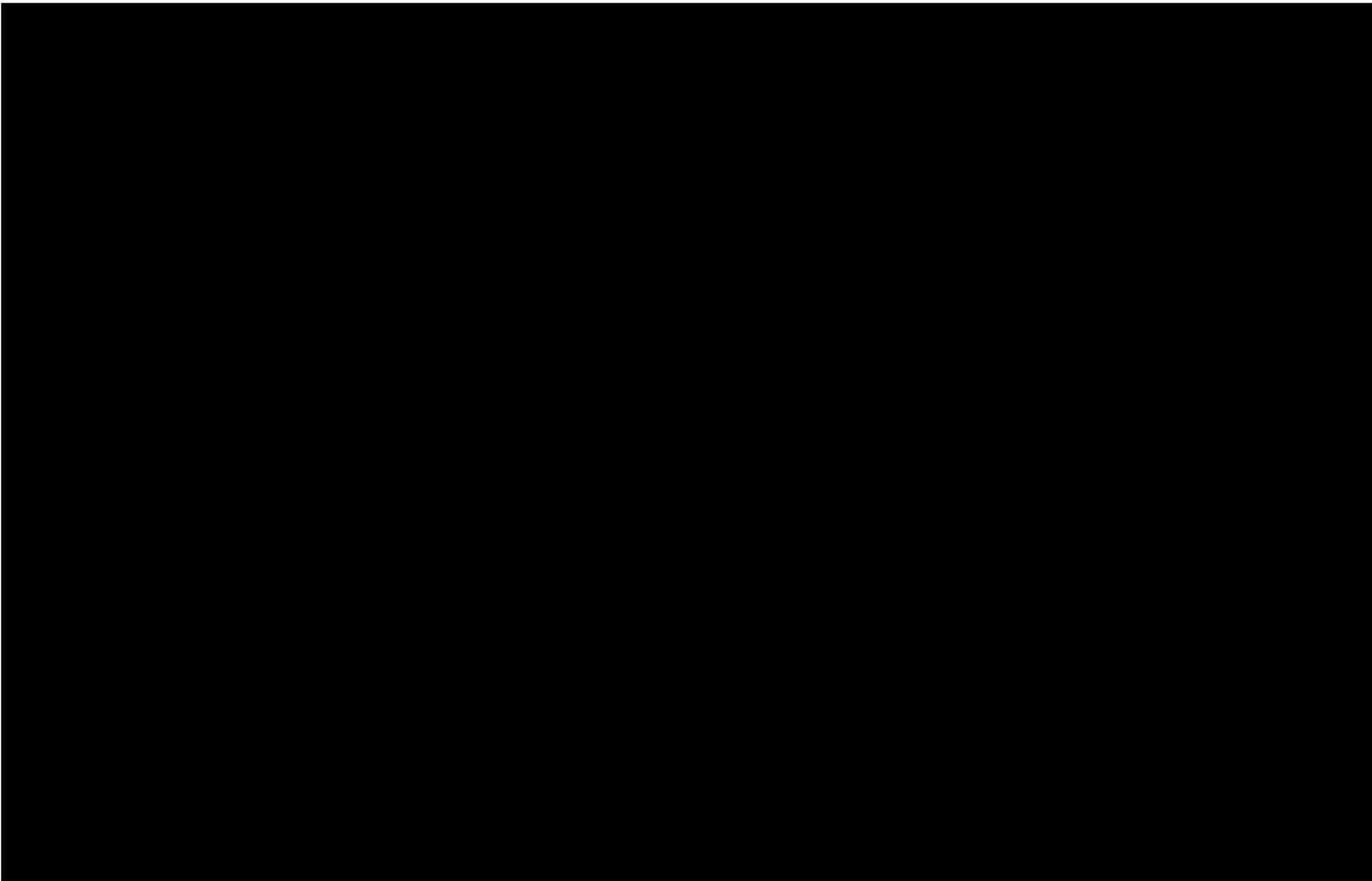


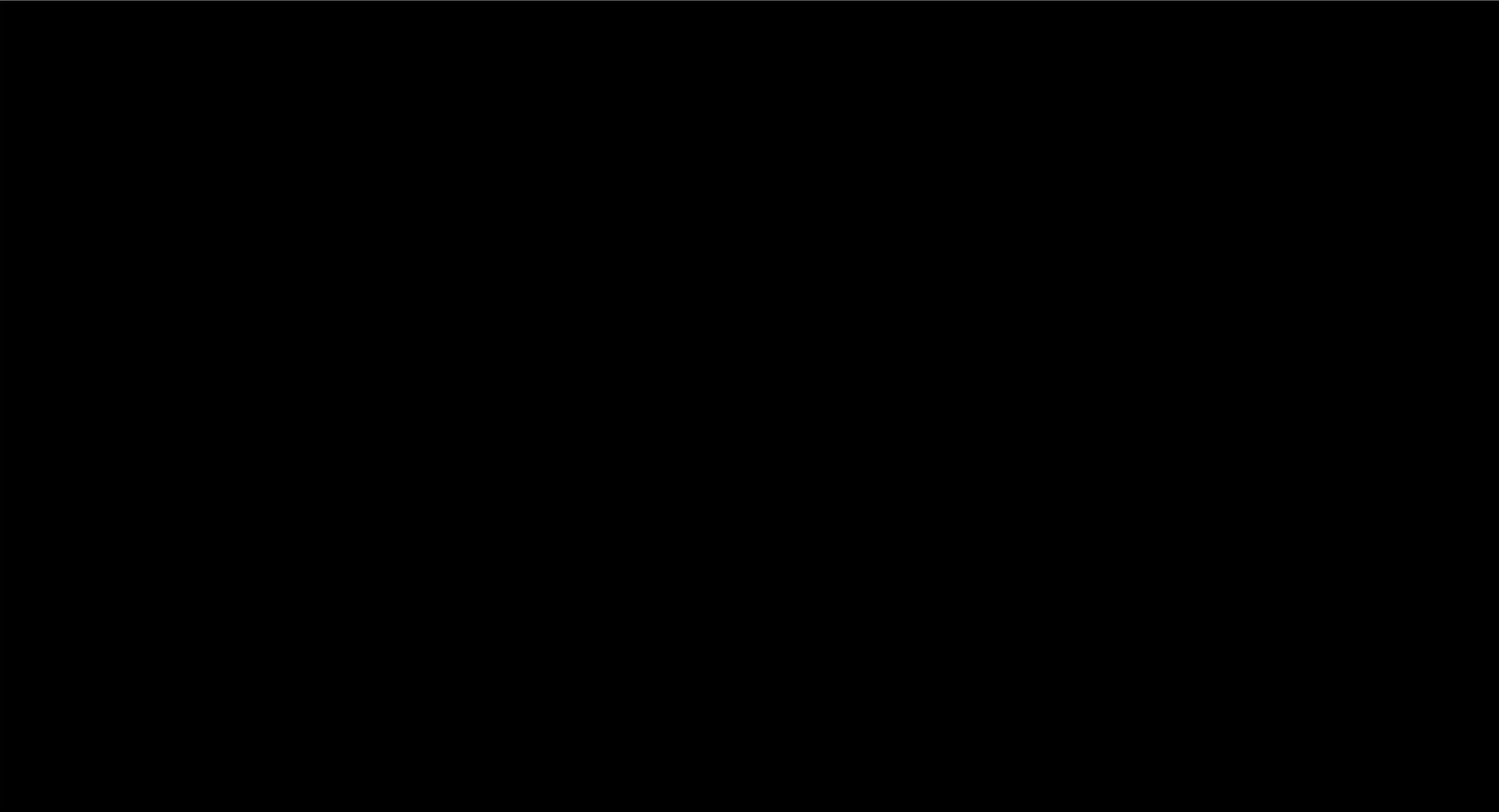


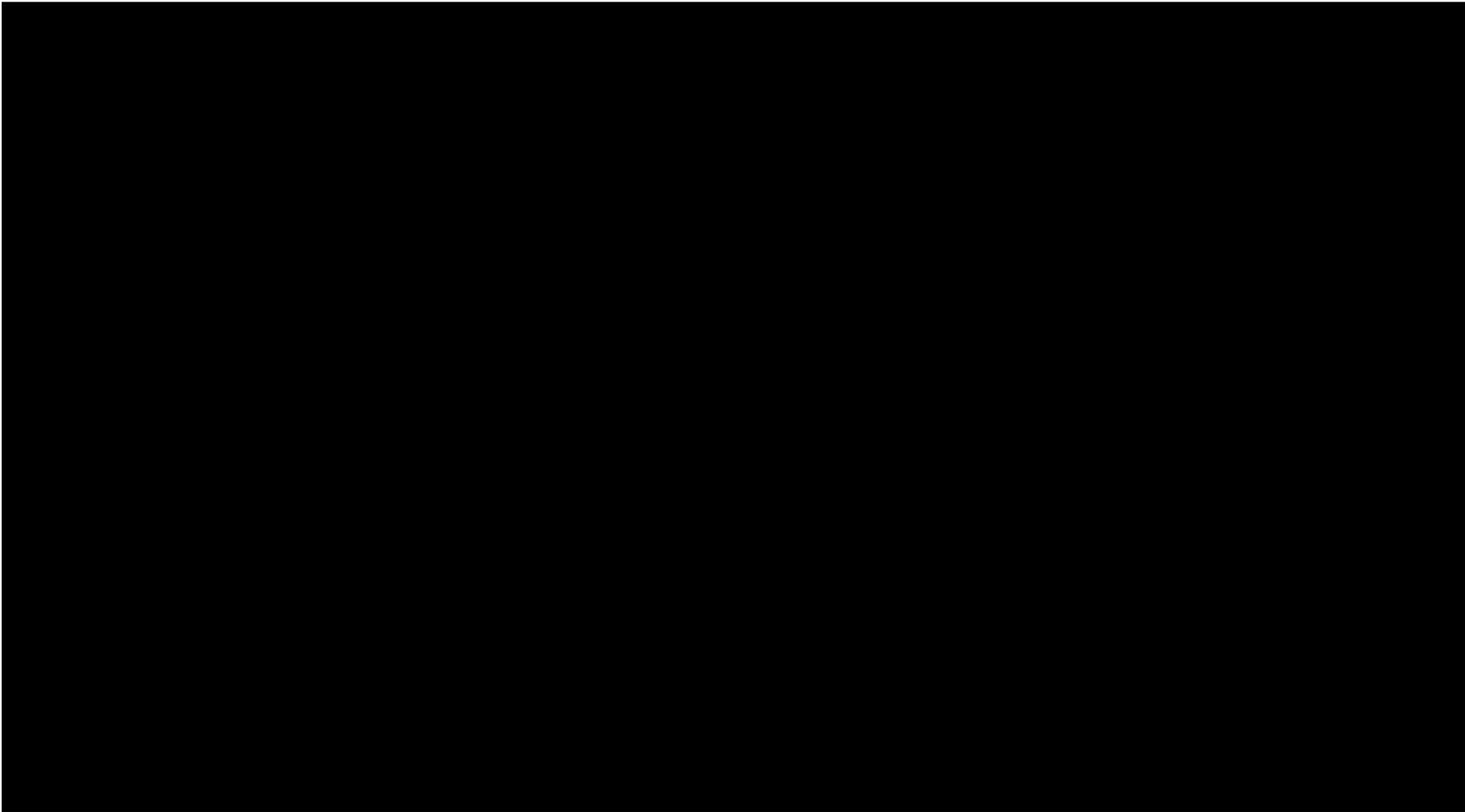


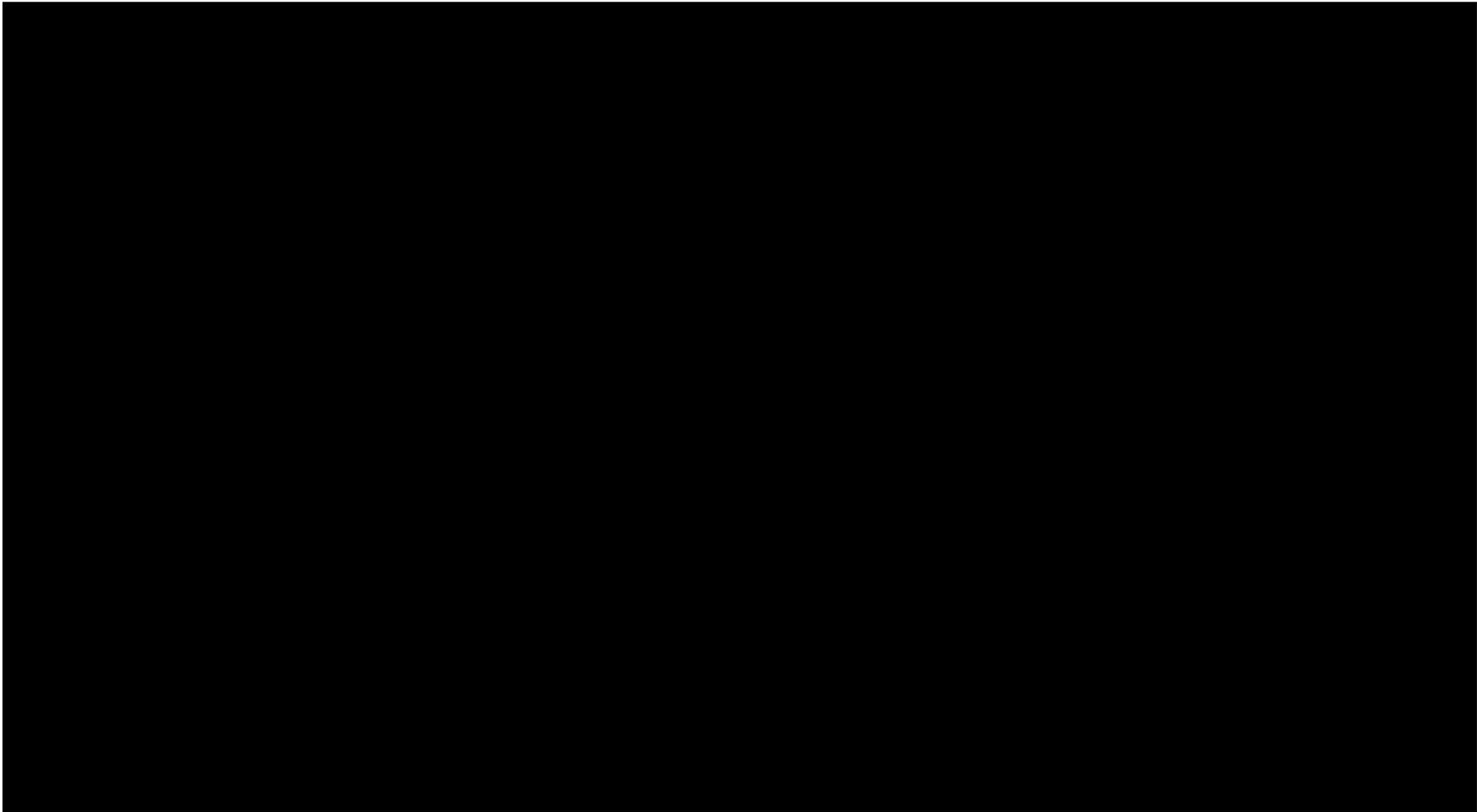


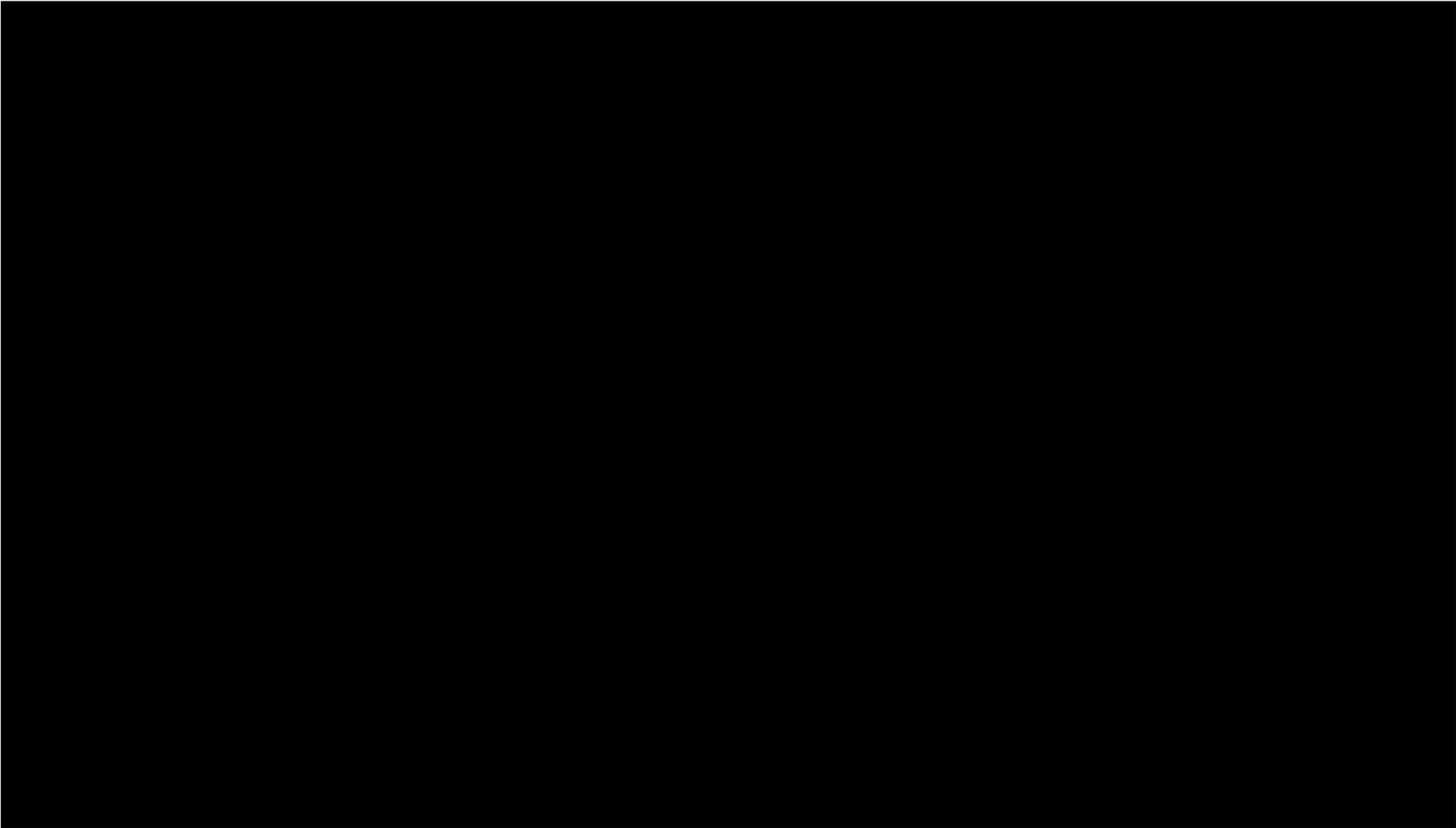


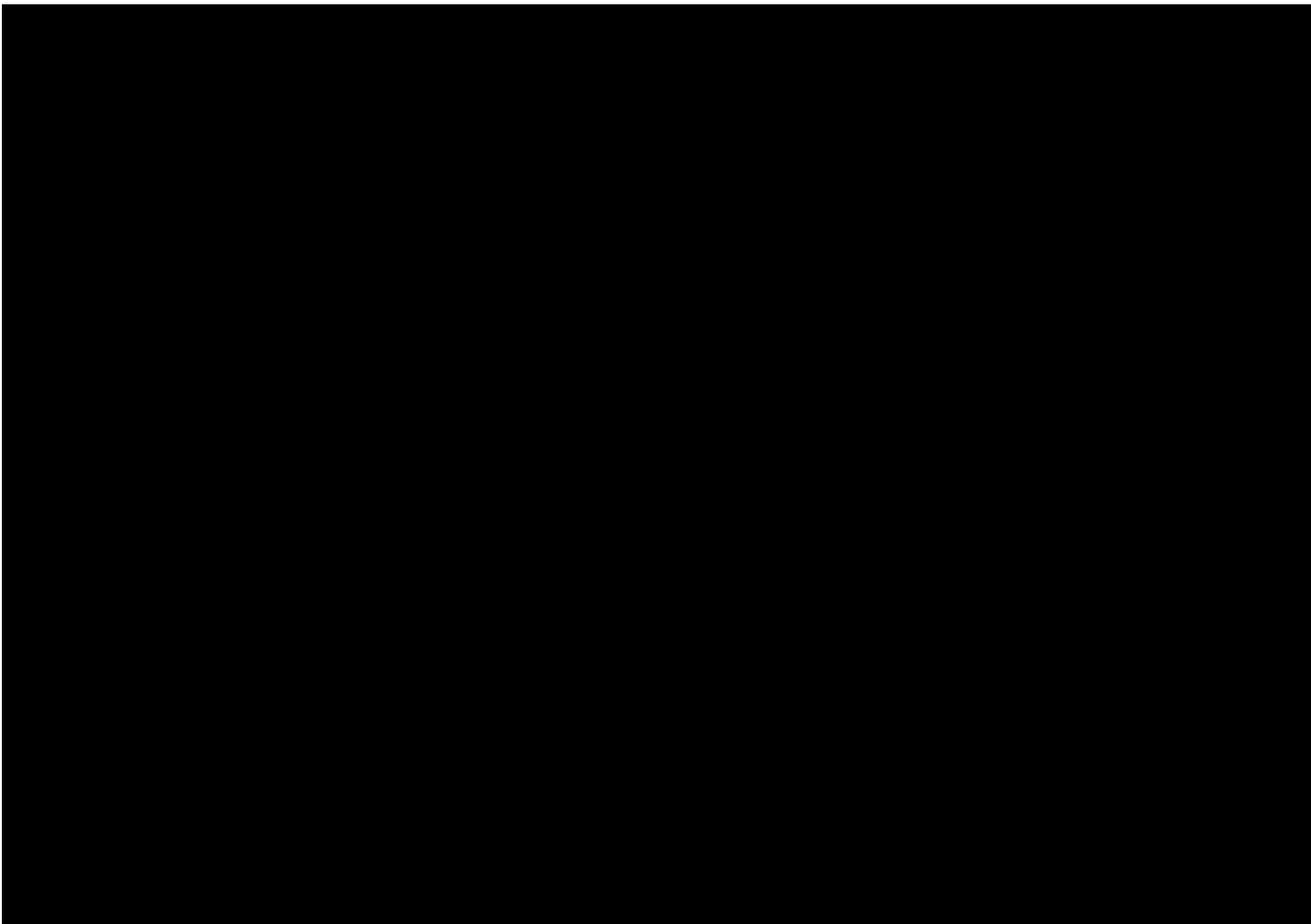


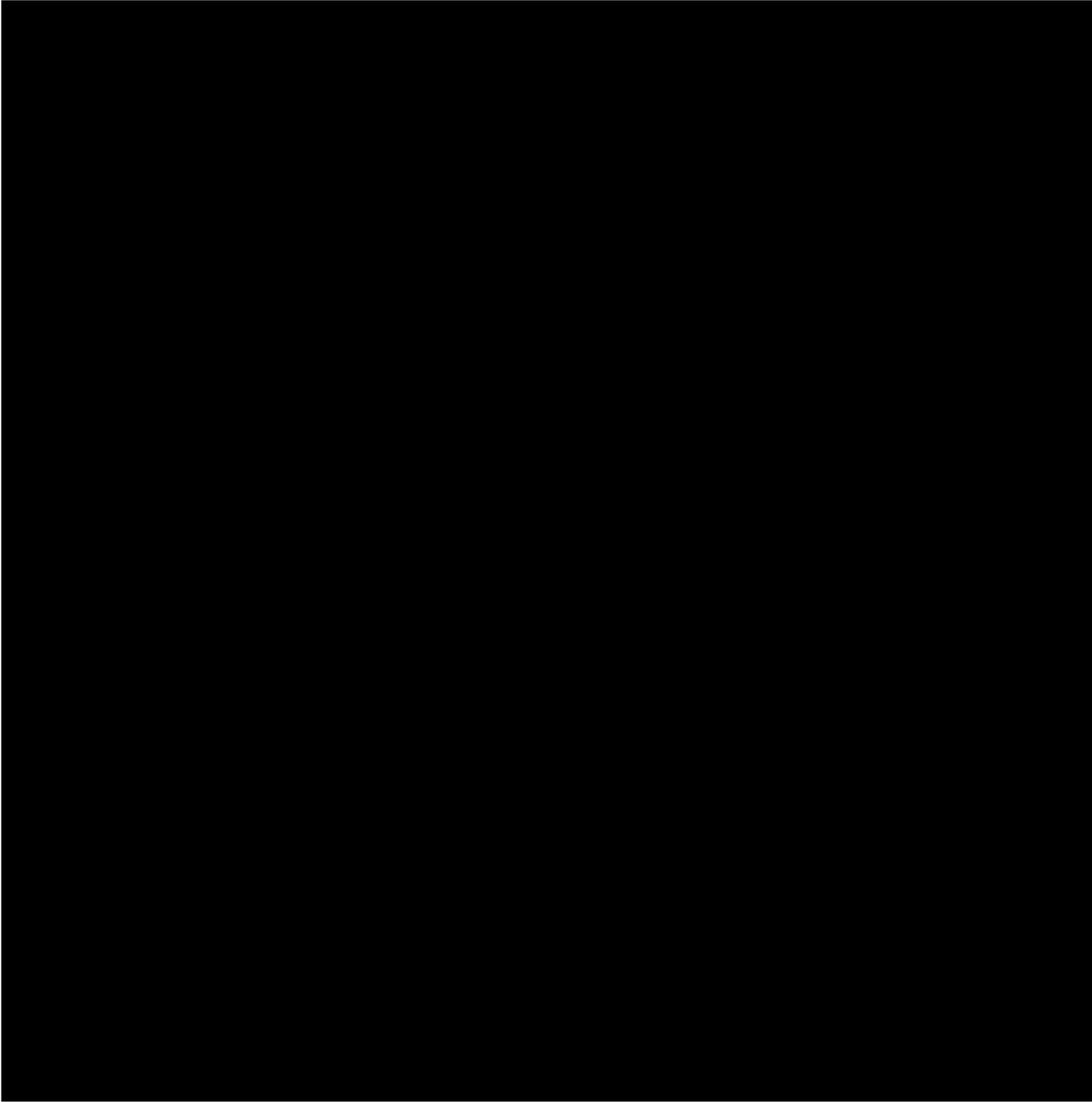


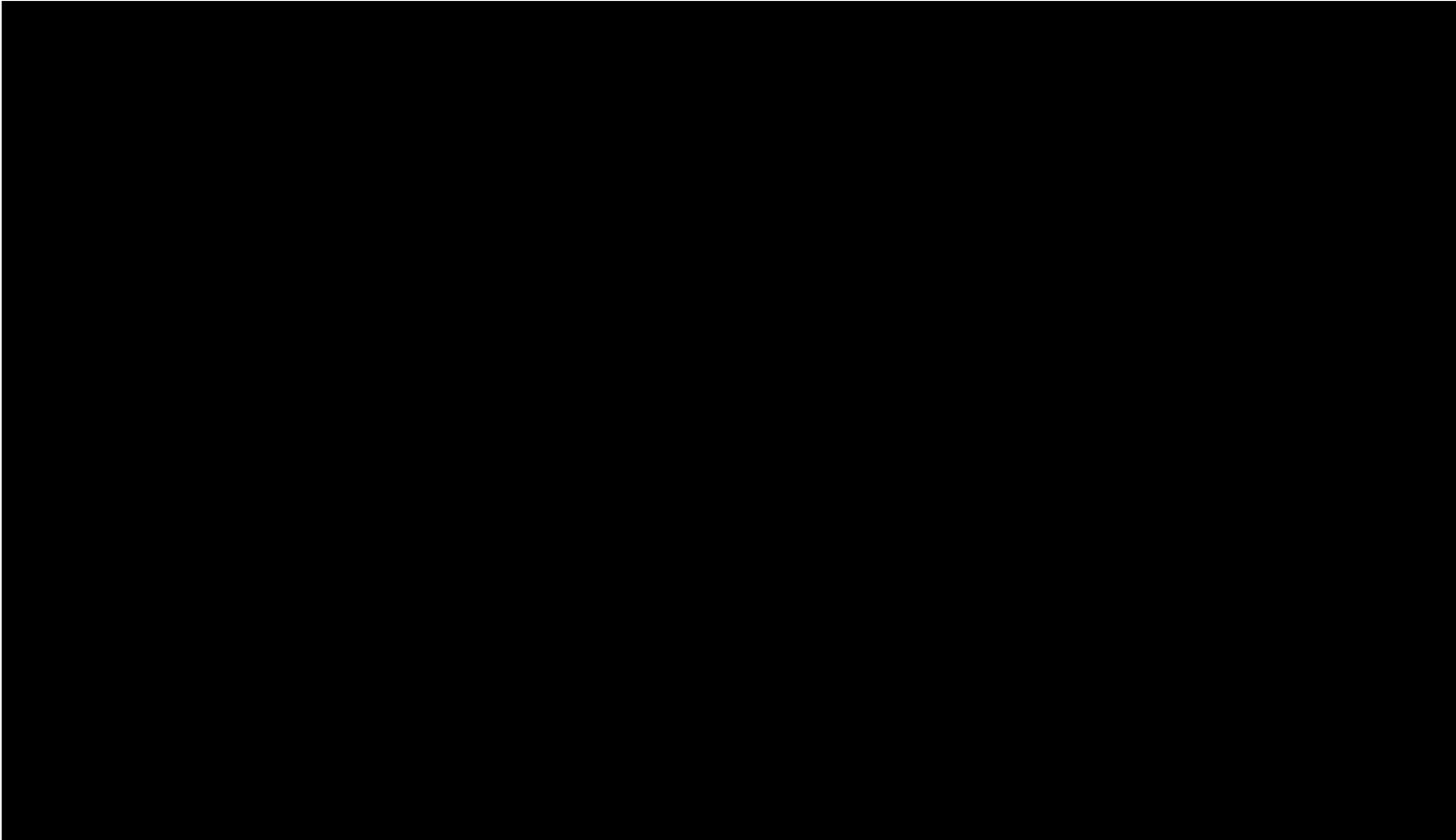


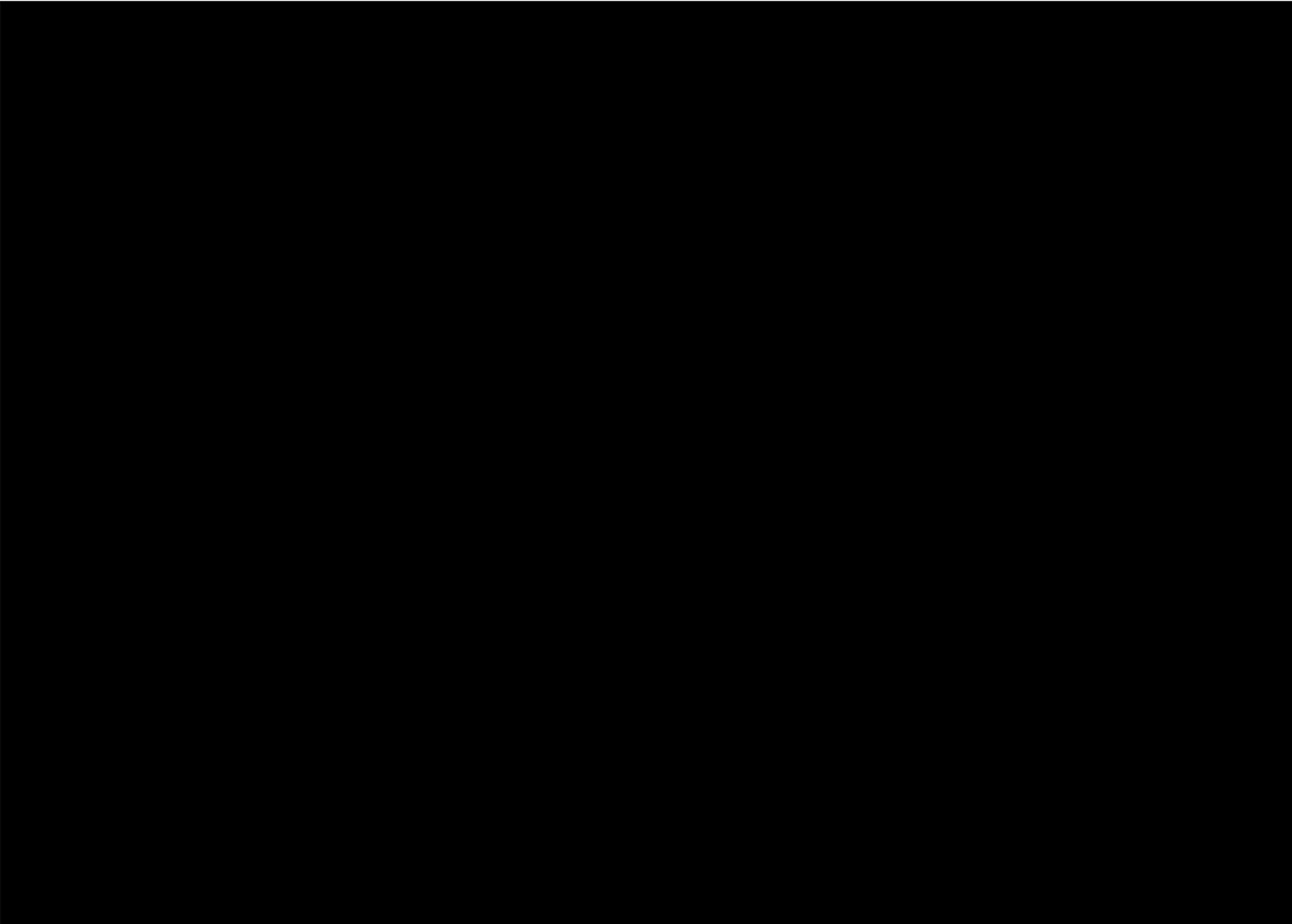


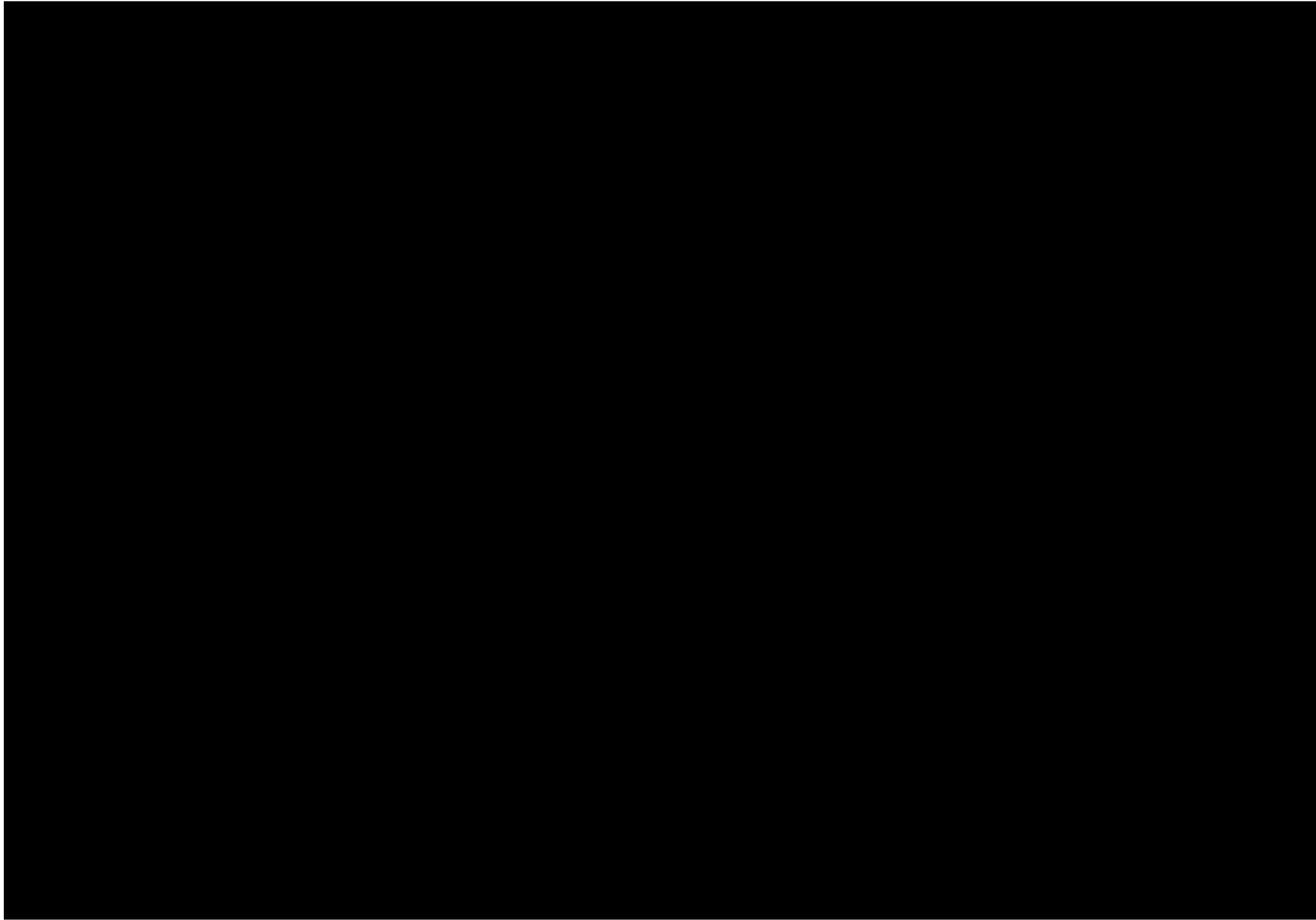


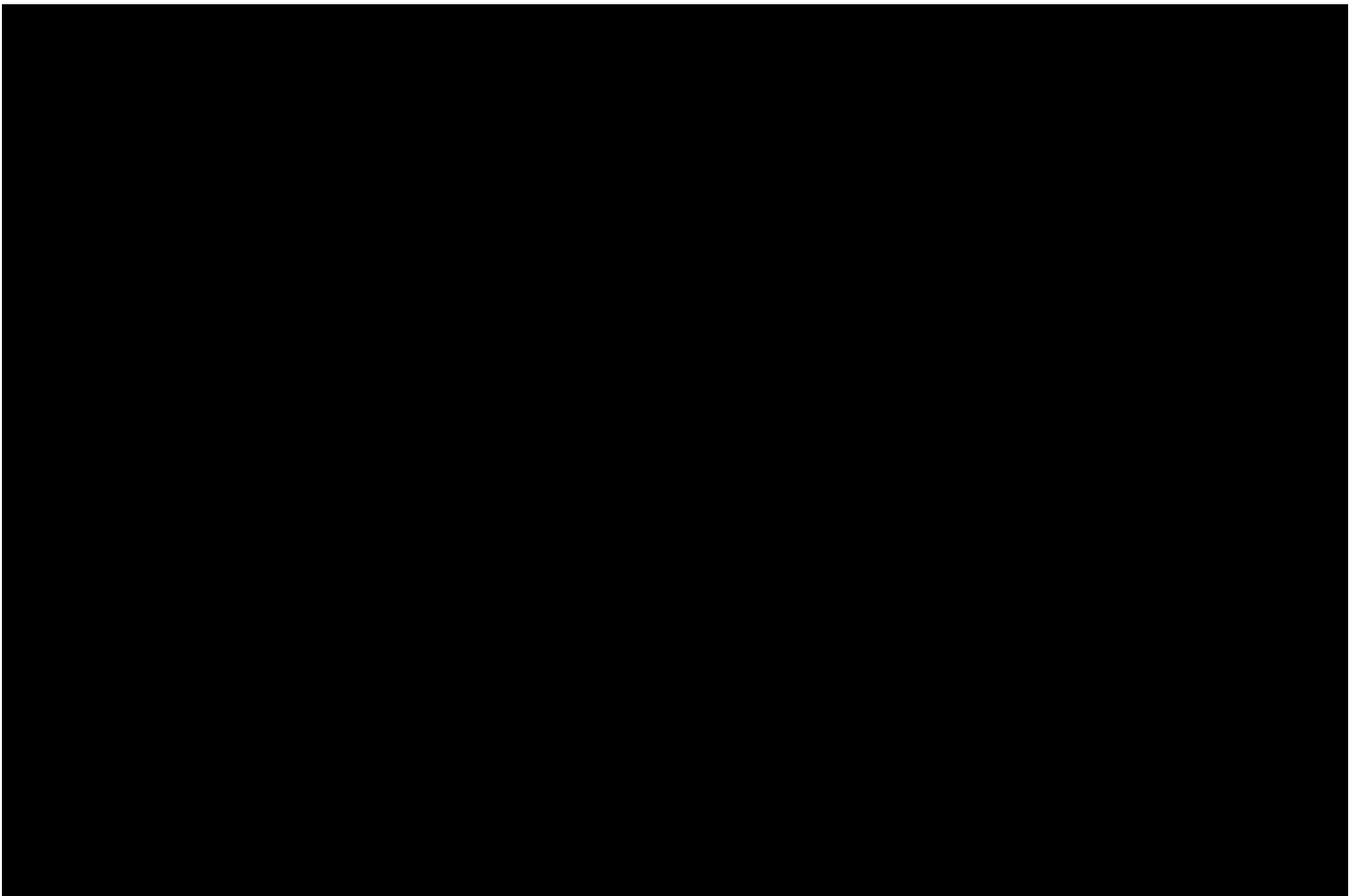




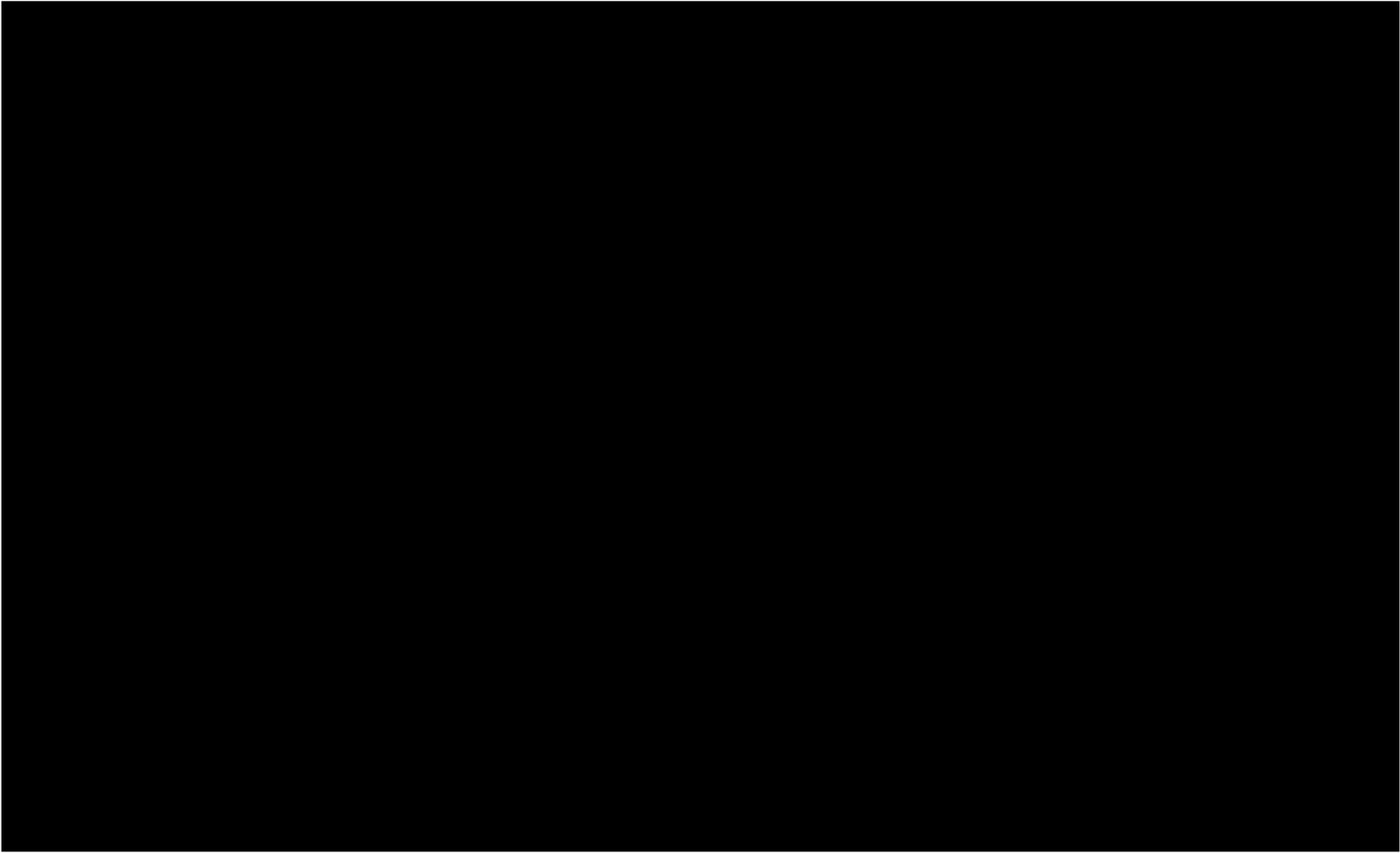




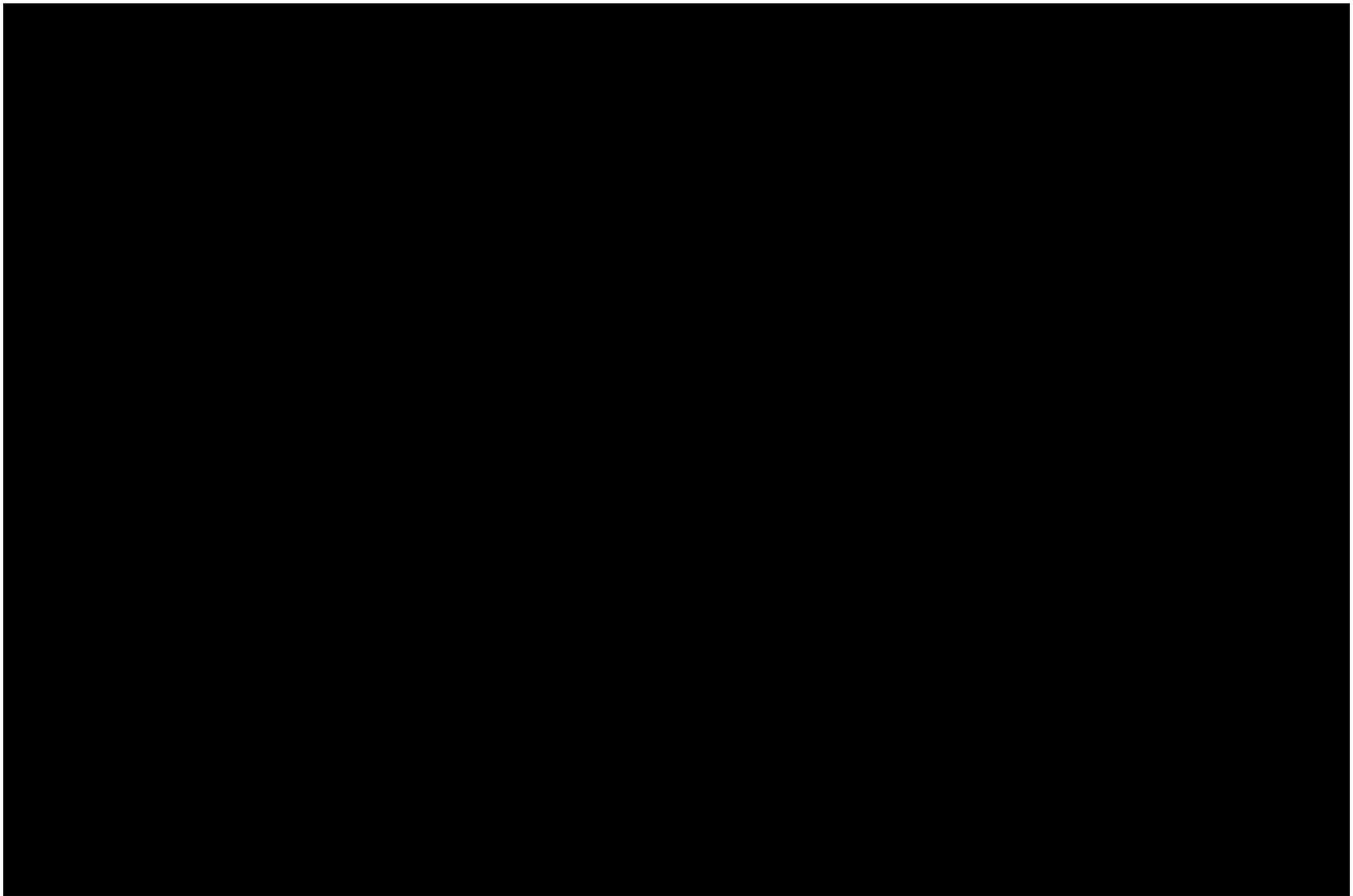




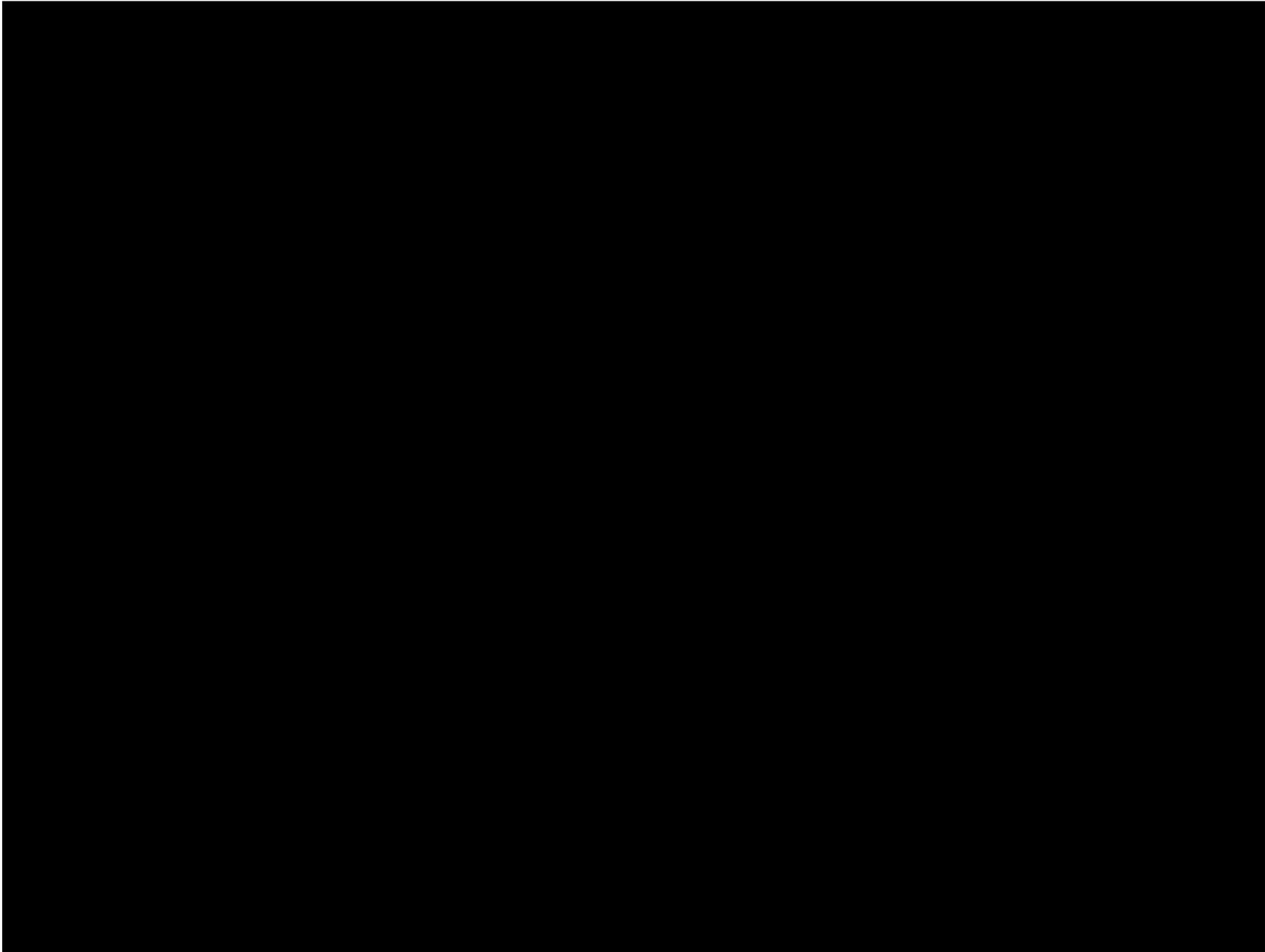




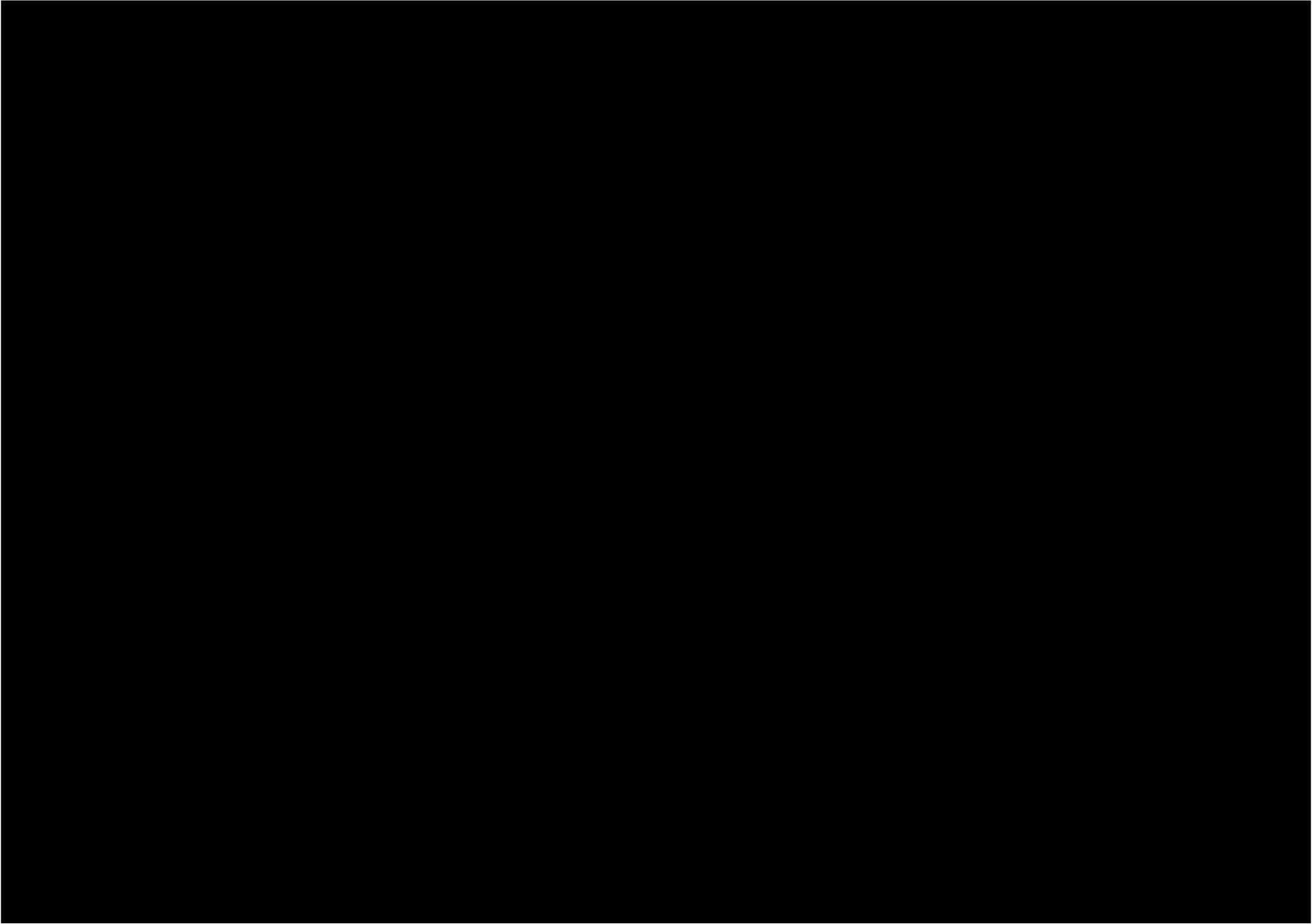




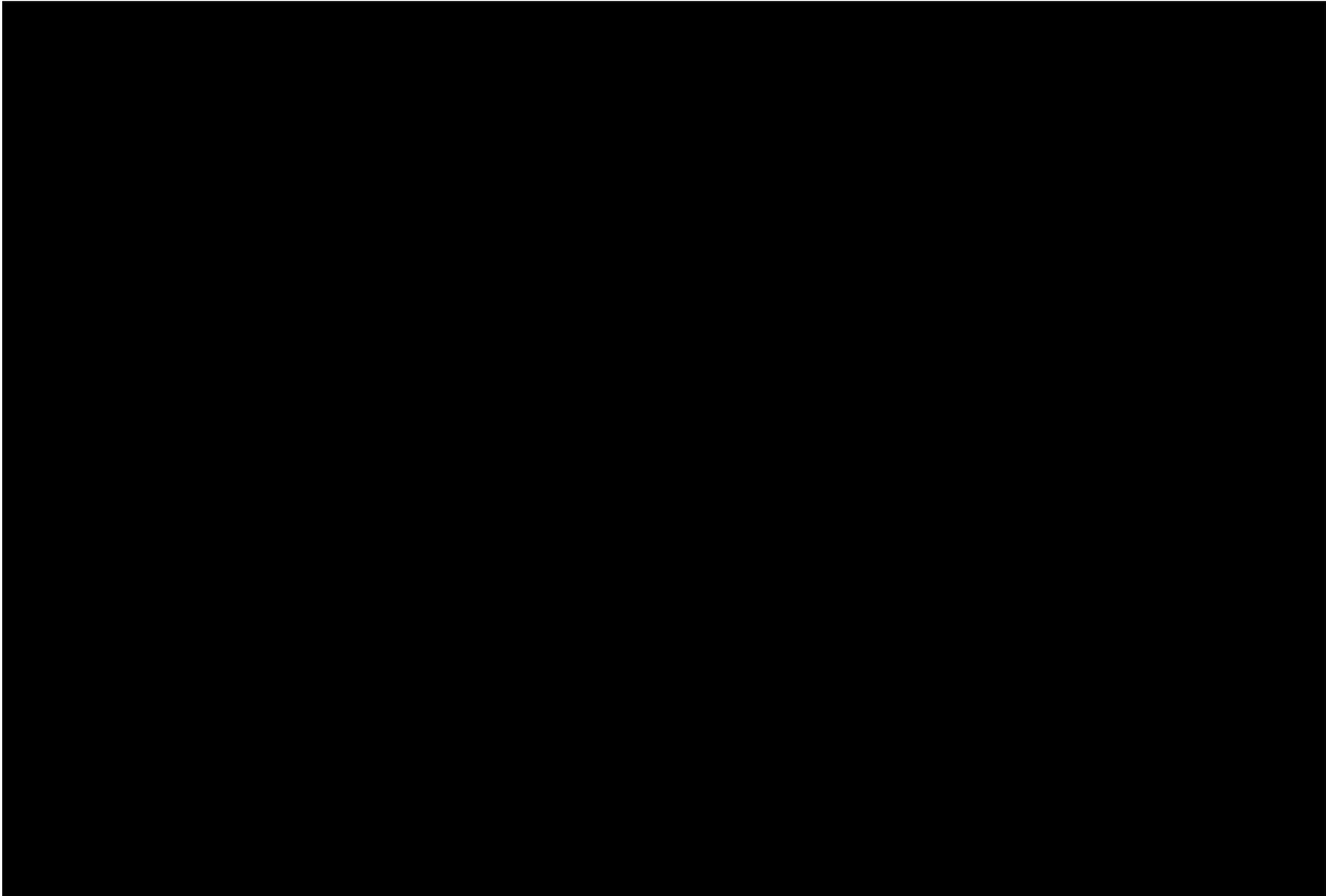
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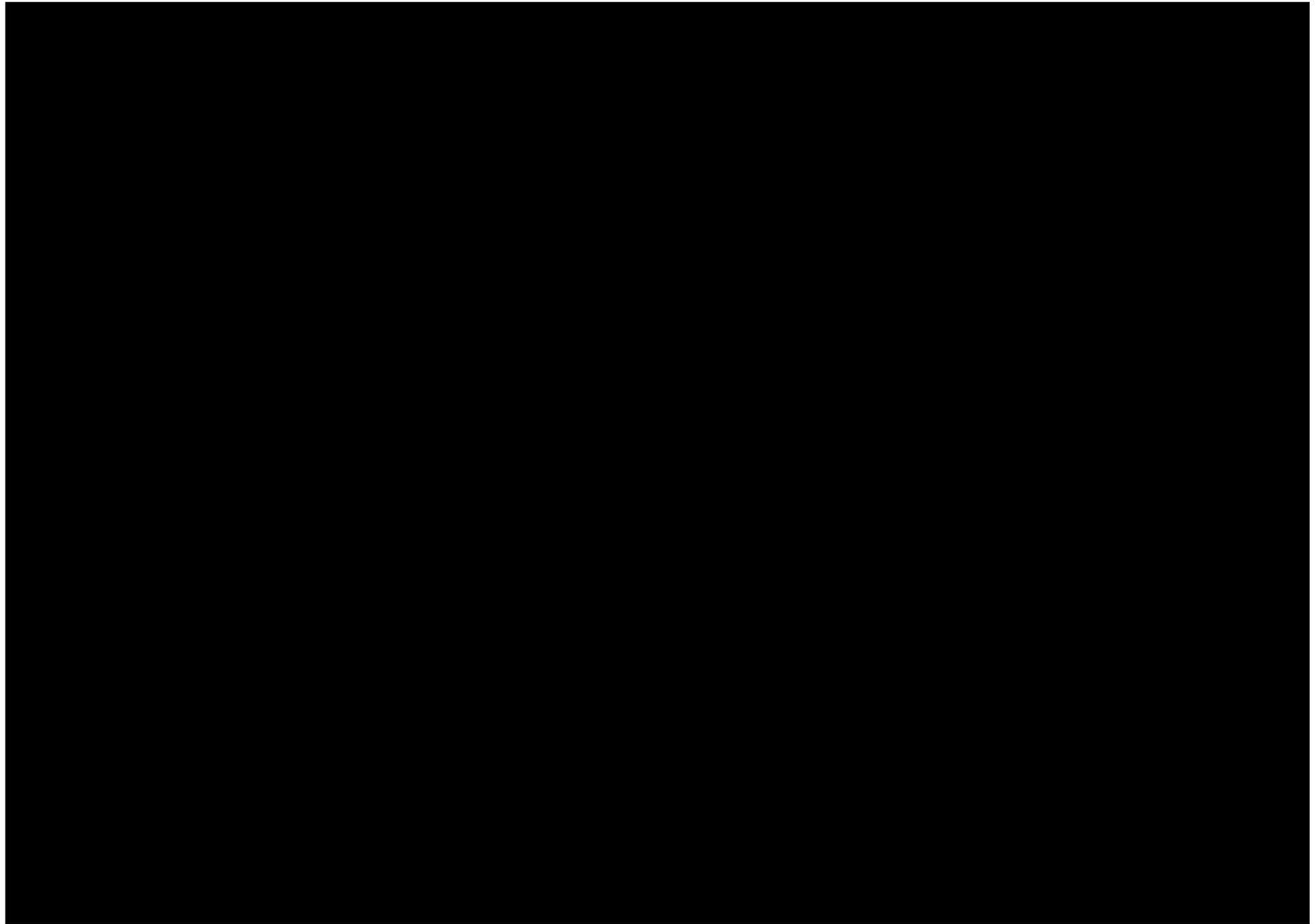
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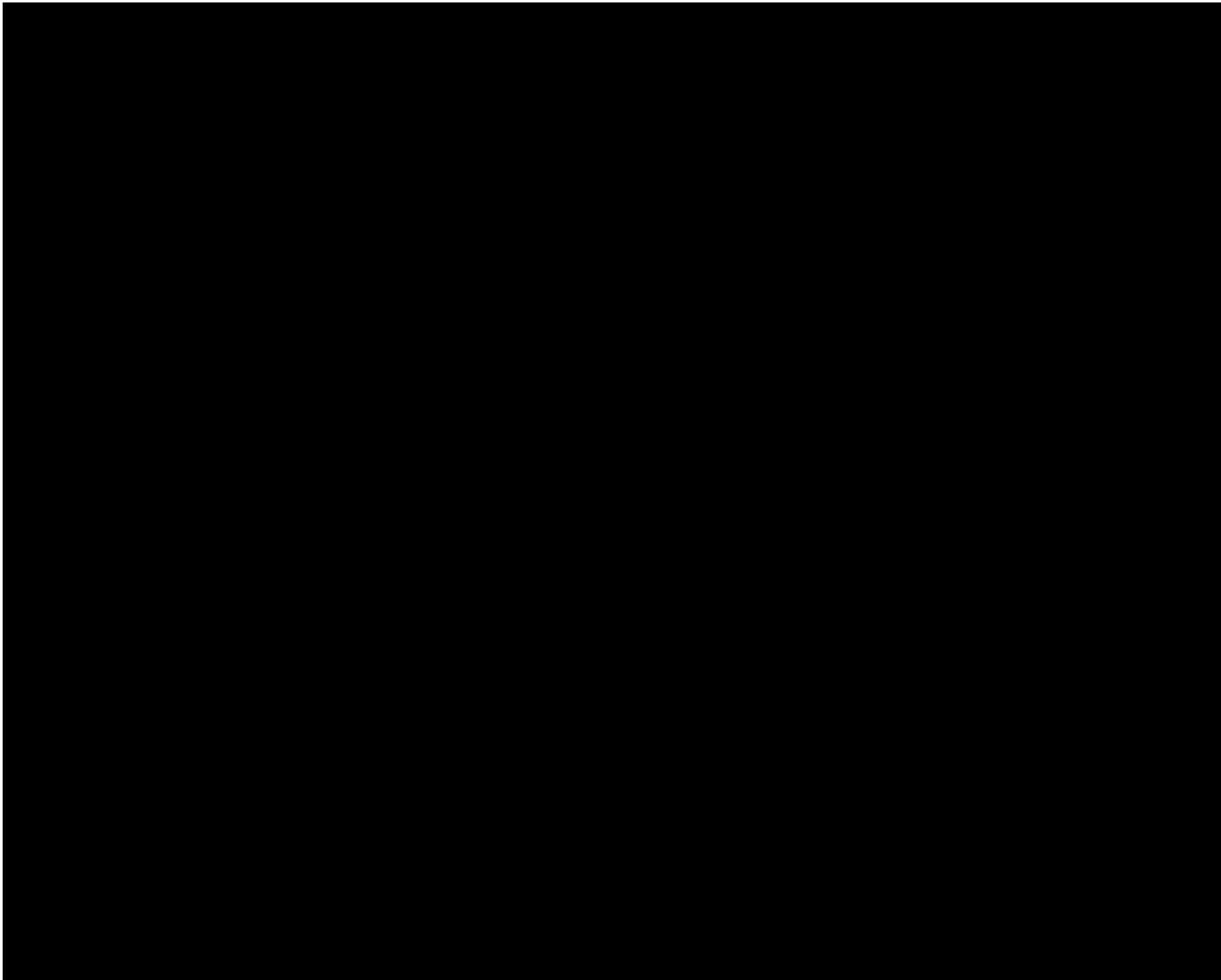
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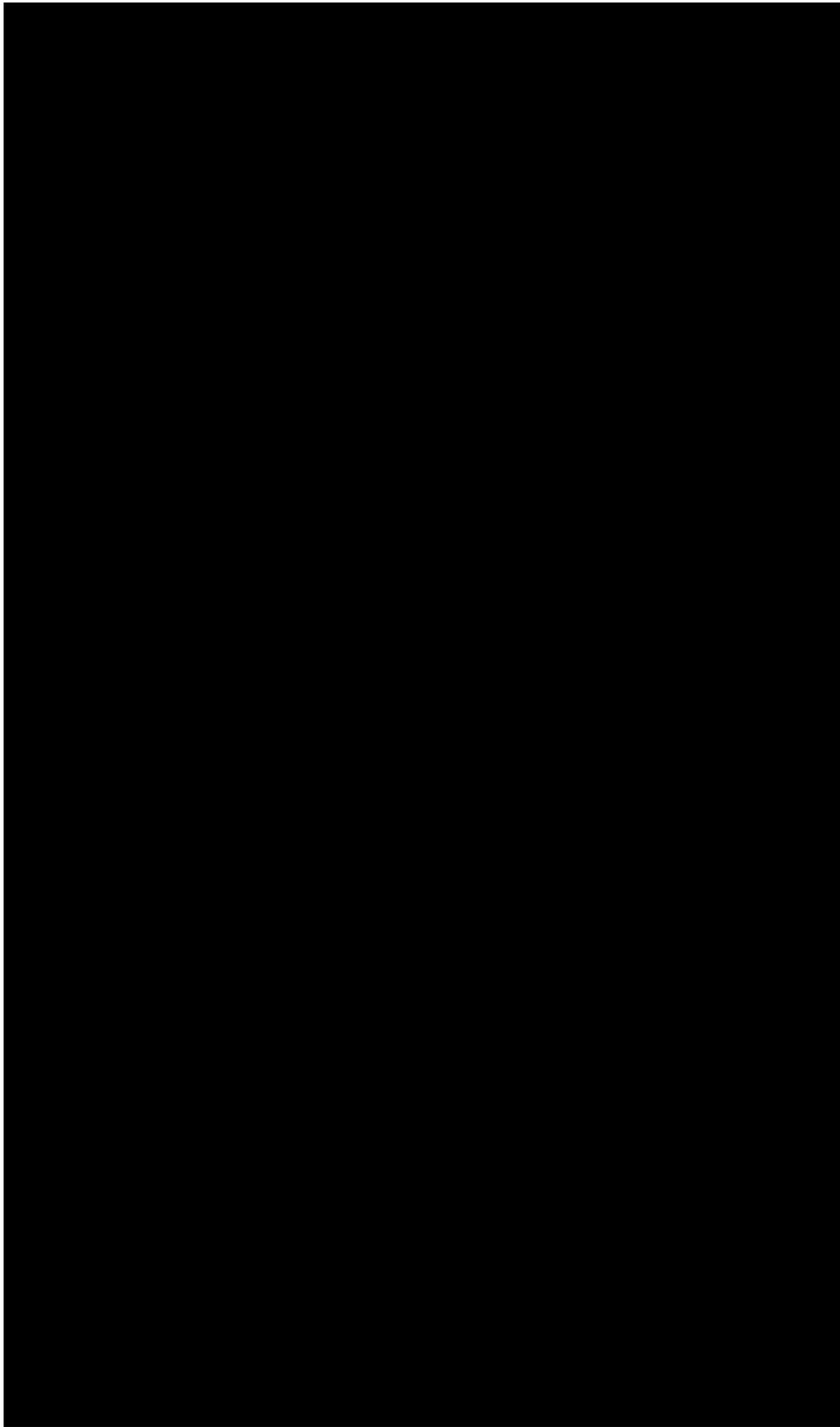


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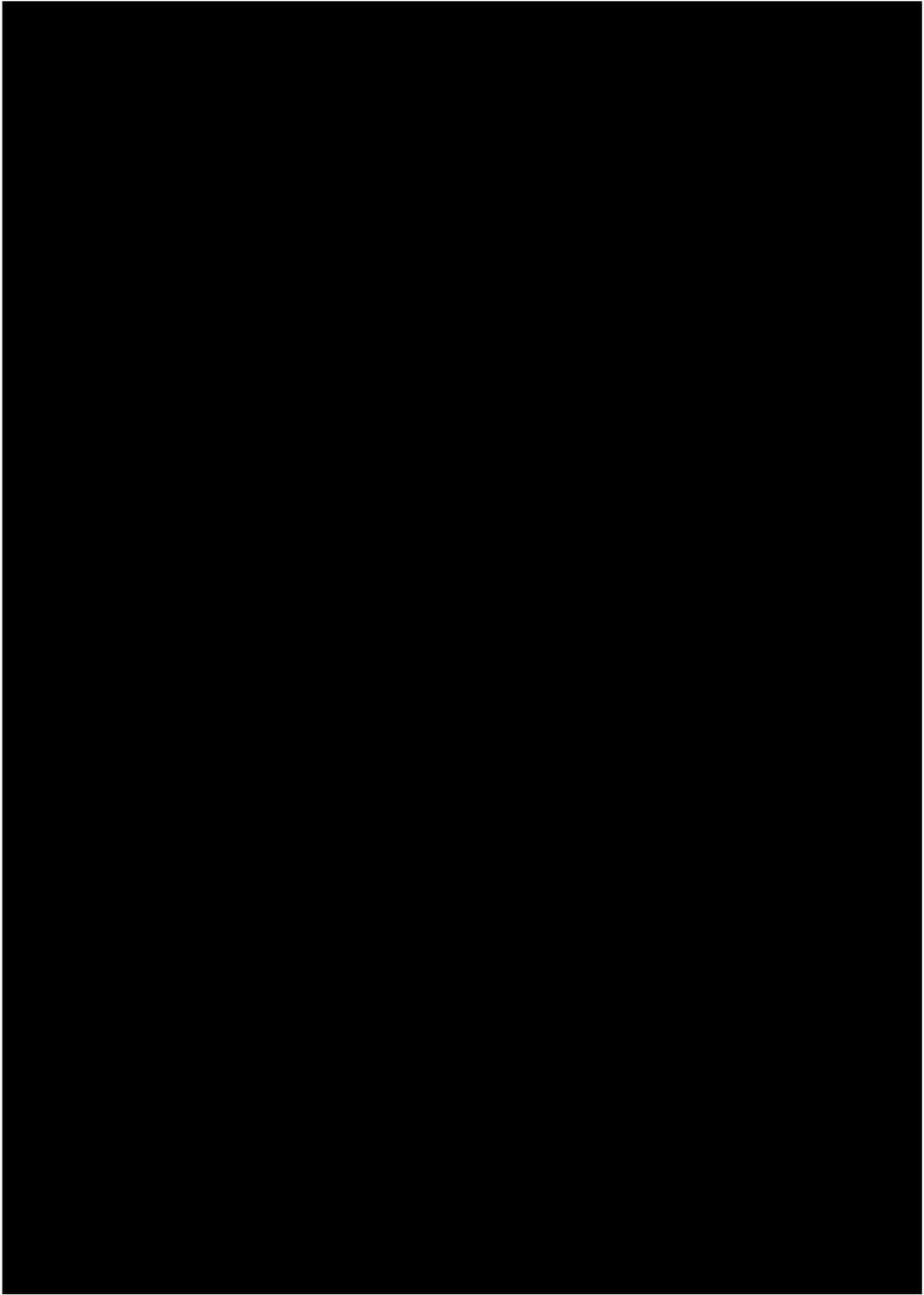


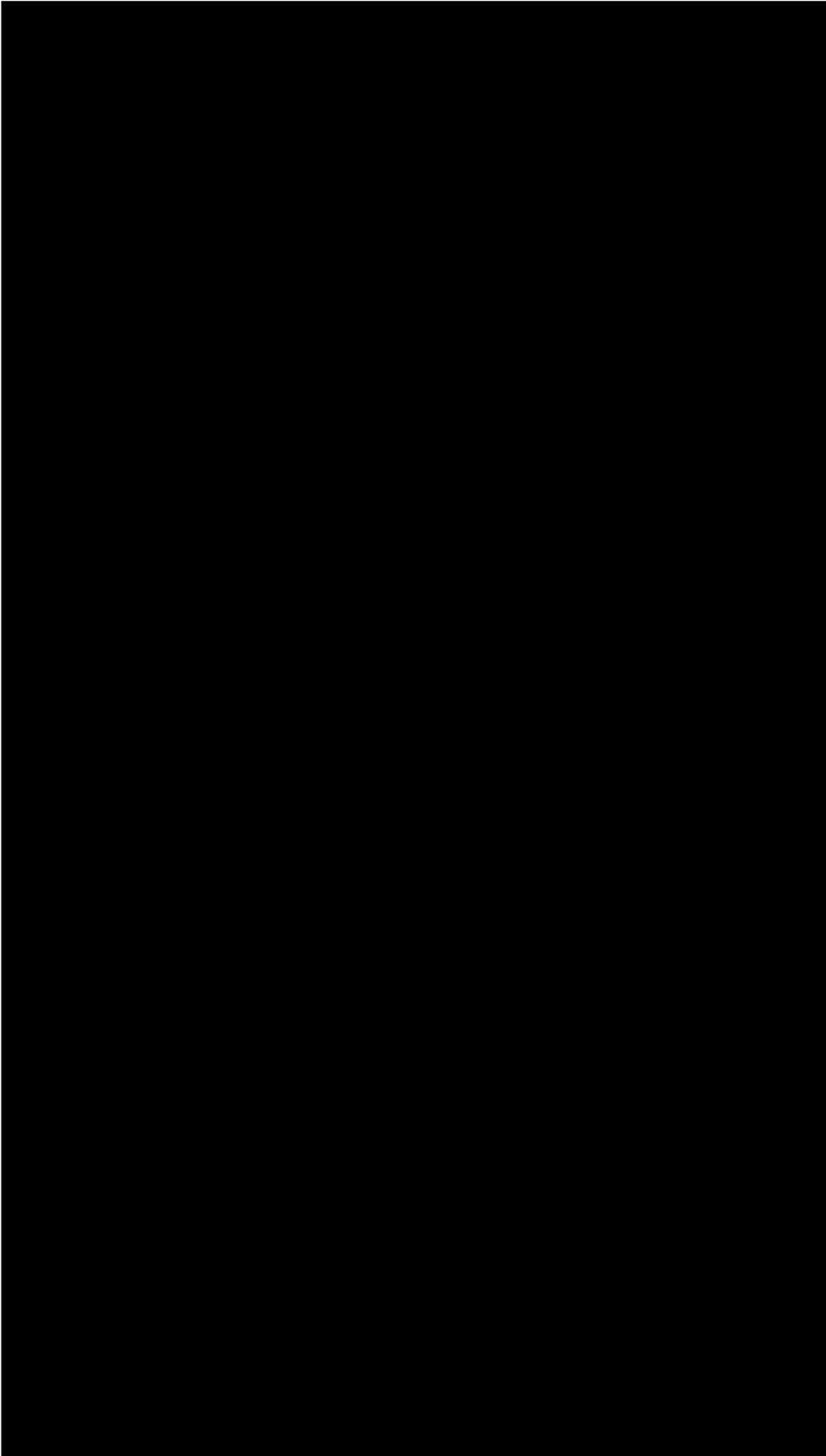
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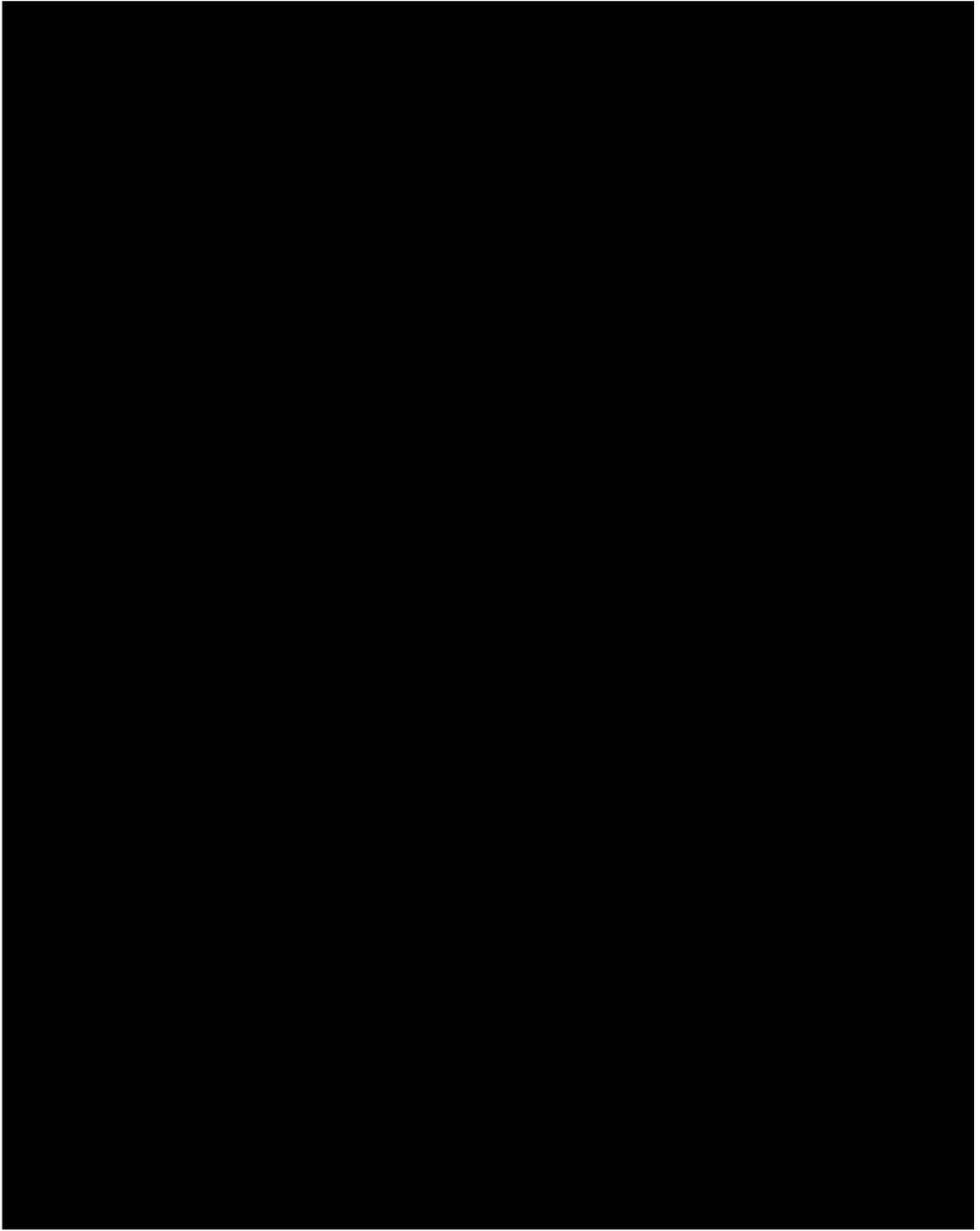
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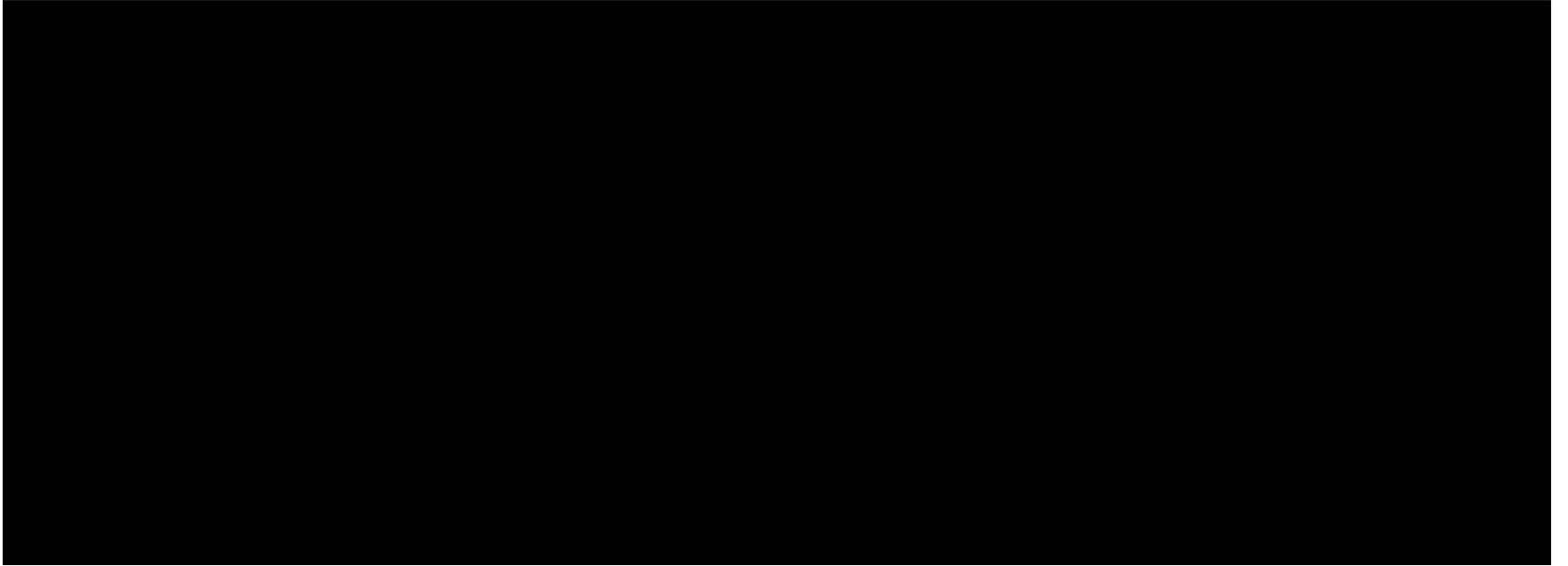


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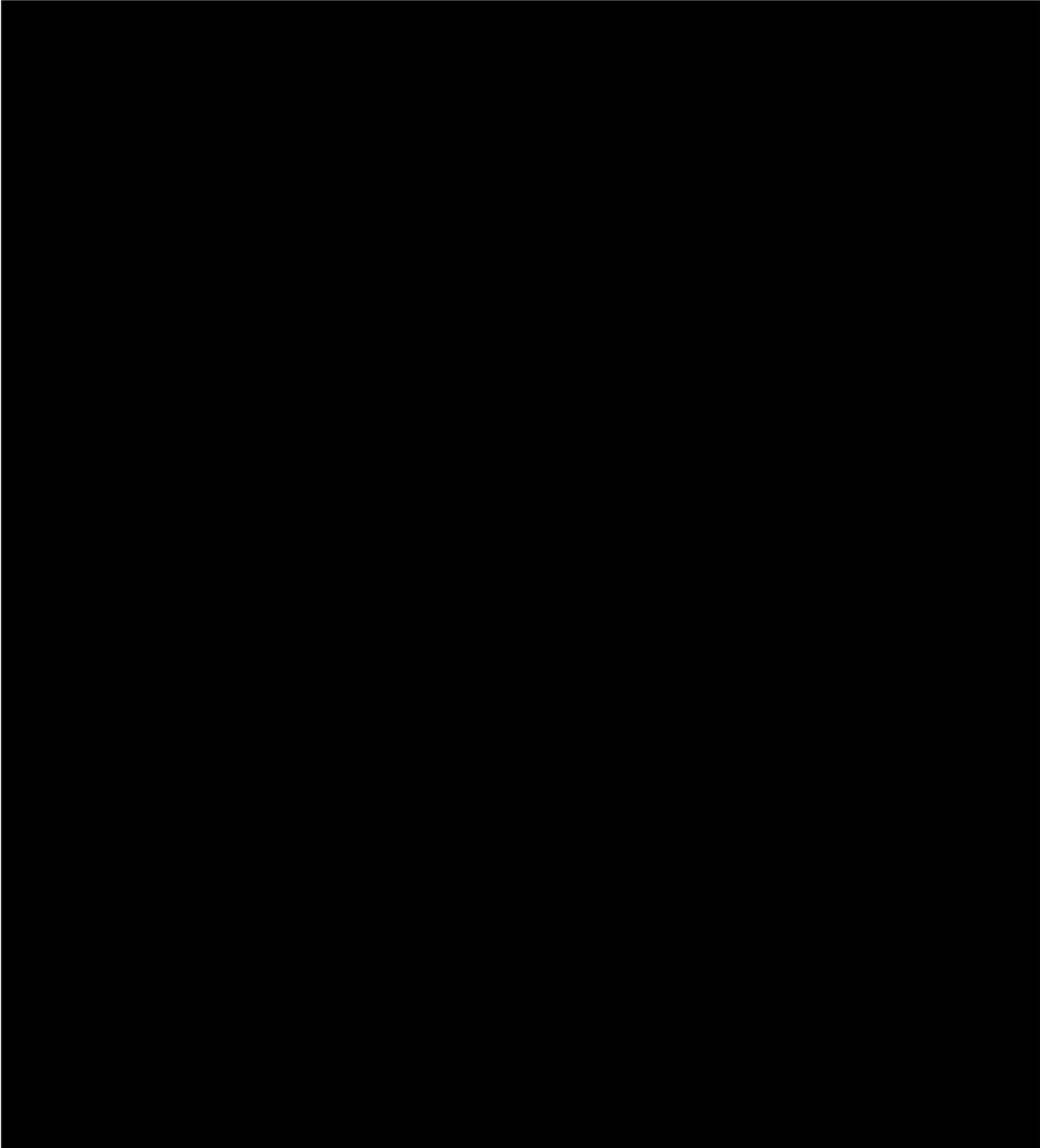


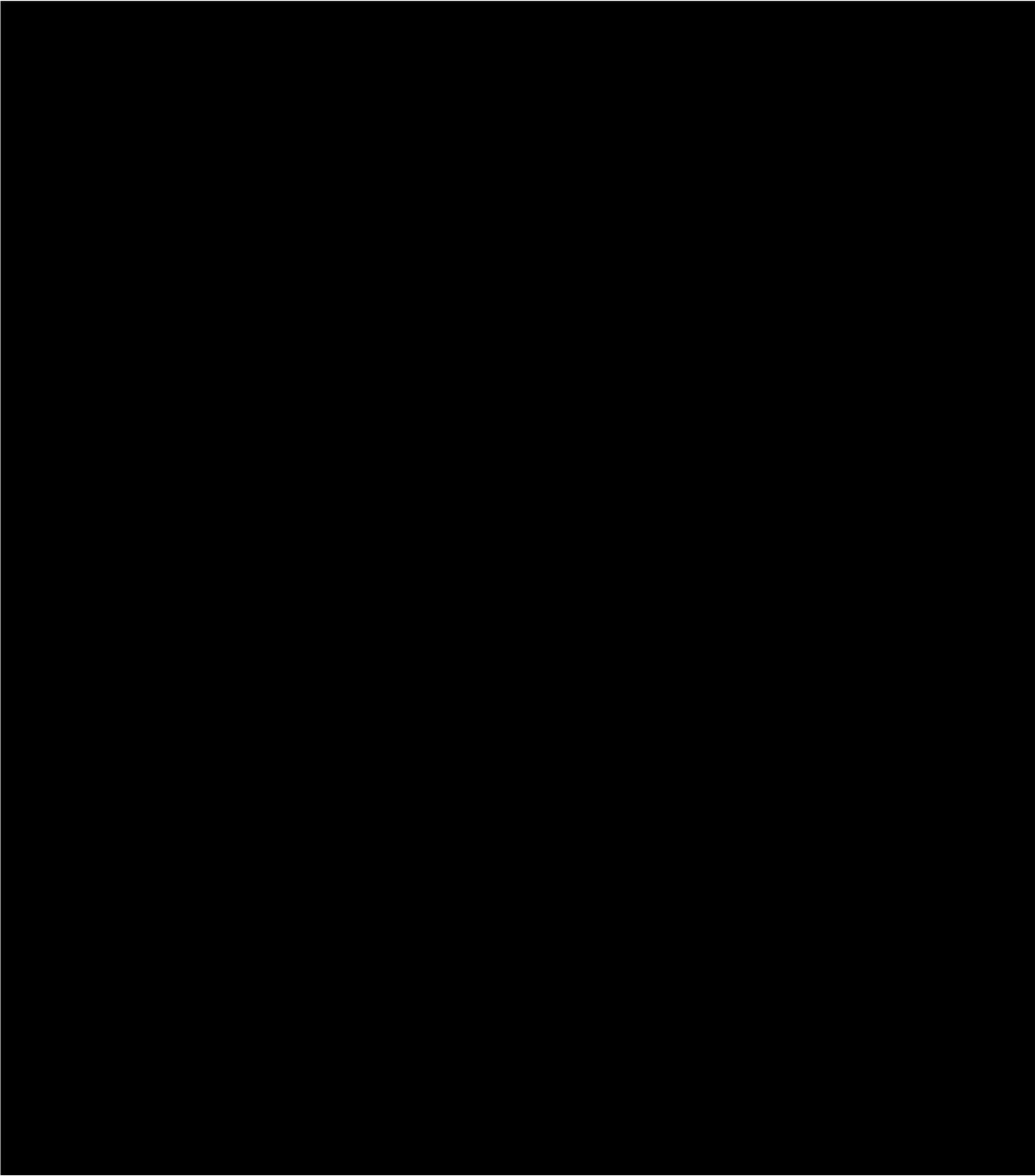


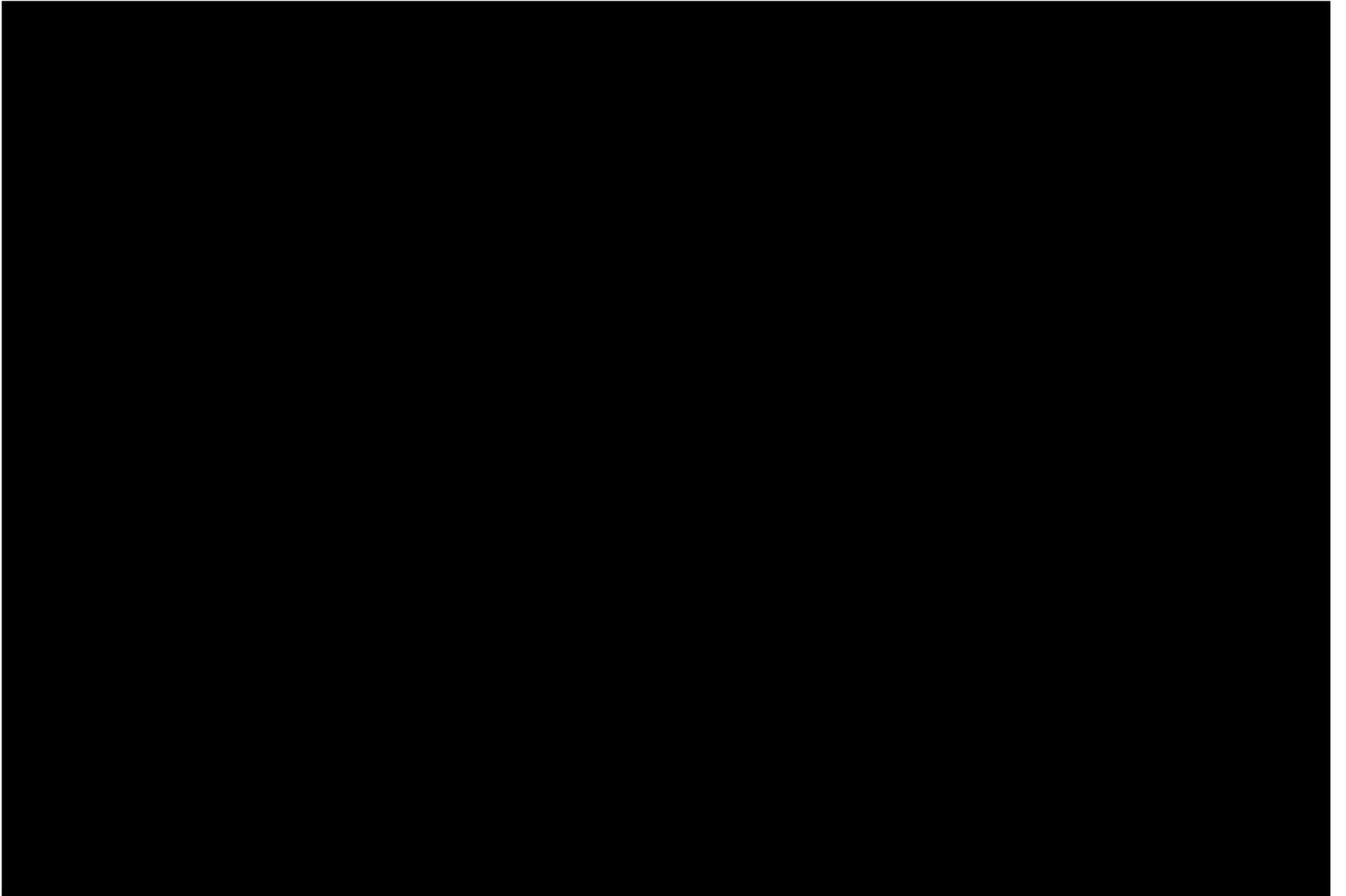




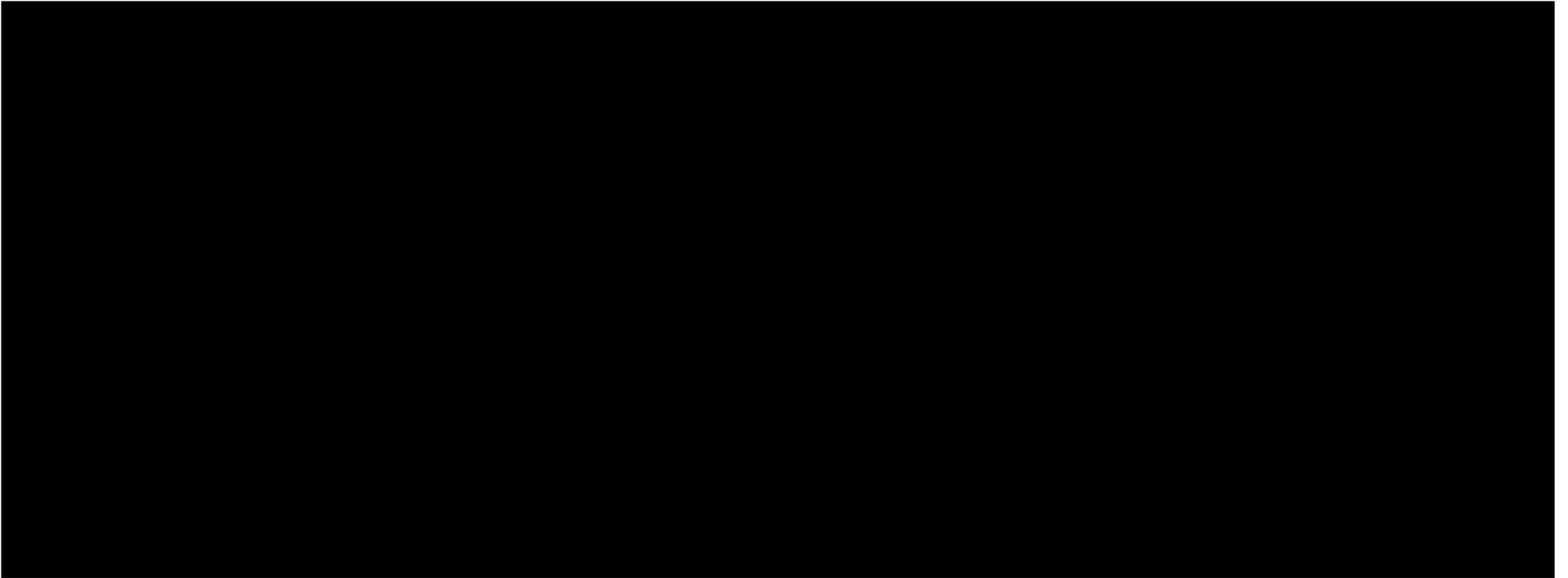
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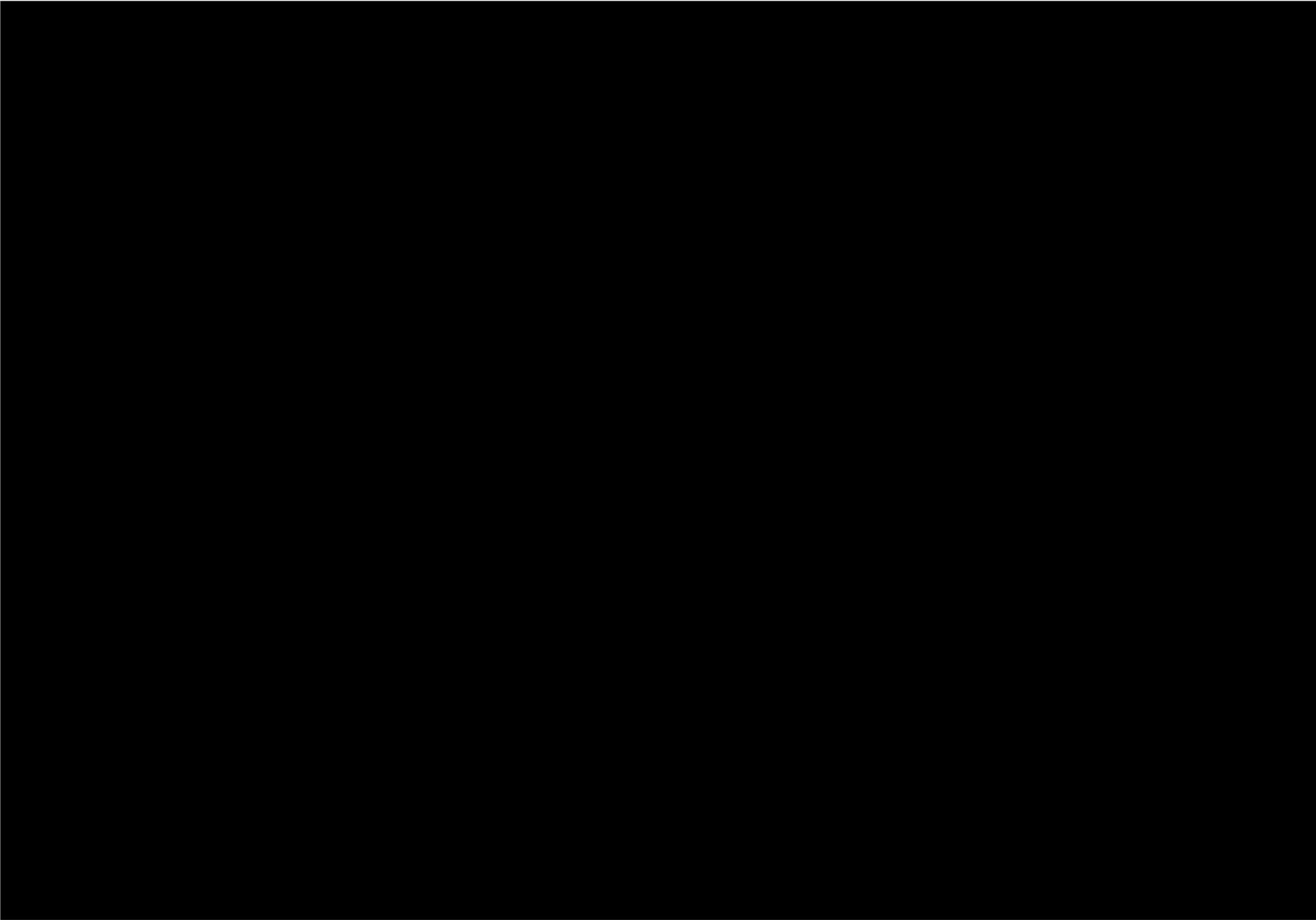




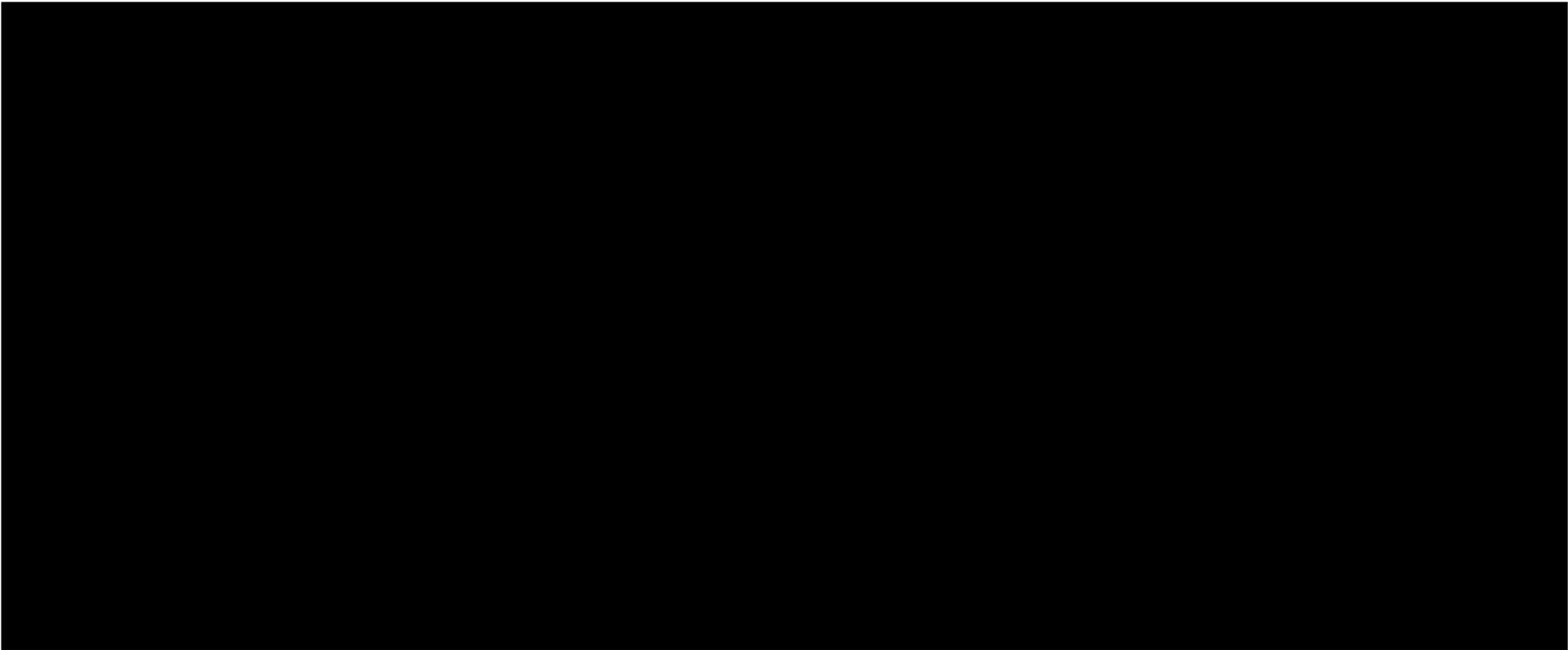
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APPENDIX A

CURRICULUM VITAE
ROGER G. NOLL

PERSONAL

Date and Place of Birth: March 13, 1940; Monterey Park, California

EDUCATION

East High School, Salt Lake City, Utah, 1958
B.S. (Math, Honors), California Institute of Technology, 1962
A.M., Ph.D. (Economics), Harvard University, 1965, 1967

SCHOLARSHIPS, FELLOWSHIPS AND AWARDS

National Merit Scholarship 1958-62
National Defense Education Act Fellowship 1962-66 (declined)
Harvard Prize Fellowship 1962-63
National Science Foundation Fellowship 1963-64
Guggenheim Fellow 1983-84
Rhodes Prize for Undergraduate Teaching, Stanford University, 1994
Distinguished Service Award, Public Utilities Research Center, University of Florida, 2001
Distinguished Lecture Award, Brookings-AEI Joint Center on Regulation and Markets, 2006
Alfred E. Kahn Distinguished Career Award, American Antitrust Institute, 2012
Distinguished Member Award, Transportation and Public Utilities Group, American Economic Association, 2013

POSITIONS HELD

Instructor, California Institute of Technology, 1965-67
Assistant Professor, California Institute of Technology, 1967-69
Senior Staff Economist, Council of Economic Advisers, 1967-68
Associate Professor, California Institute of Technology, 1969-71
Senior Fellow and Co-director, Studies in the Regulation of Economic Activity, Brookings Institution, 1970-73
Professor, California Institute of Technology, 1973-82
Visiting Professor, Graduate School of Business, Stanford University, 1976-77
Chair, Division of the Humanities and Social Sciences, California Institute of Technology, 1978-82
Reuben Gustavson Lecturer, University of Chicago, April 1981
Institute Professor of Social Sciences, California Institute of Technology, 1982-84
Donald Gilbert Memorial Lecturer, University of Rochester, December 1982
Fellow, Center for Advanced Study in the Behavioral Sciences, 1983-84
Professor of Economics, Stanford University, 1984-2006 (*Emeritus* 2006-)
Visiting Scholar, Hoover Institution, 1984-85
Professor by Courtesy, Department of Political Science, Stanford University, 1985-2006
Professor by Courtesy, Graduate School of Business, Stanford University, 1986-2006
Veblen-Clark Lecturer, Carleton College, May 1986
Director, Public Policy Program, Stanford University, 1986-2002
David Kinley Lecturer, University of Illinois, May 1987
Sunderland Fellow, Law School, University of Michigan, Fall 1988
Morris M. Doyle Centennial Professor in Public Policy, Stanford University, 1990-2002
Jean Monnet Professor, European University Institute, Spring 1991
Associate Dean, Humanities and Sciences, Stanford University, 1991-92
Visiting Professor, University of California, San Diego, 1993

Visiting Fellow, Brookings Institution, 1995-96
Nonresident Senior Fellow, Brookings Institution, 1996-99
Director, American Studies Program, Stanford University, 2001-02
Visiting Scholar, London School of Economics, Spring 2001 and Spring 2002
Senior Fellow, American Antitrust Institute, 2002-
Director, Stanford Center for International Development, 2002-06
Kim Thomas Lecturer, Whittier College, 2010

TEACHING EXPERIENCE

Undergraduate: Introductory Economics, Intermediate Microeconomic Theory, Introduction to Econometrics, Antitrust and Regulation, Economic History of Medieval Europe, History of Economic Thought, Economic Policy Analysis, Economics of Sports, Political Economy of the West

Graduate: Antitrust and Regulation, Economic Policy Analysis, Applied Microeconomic Theory, Experimental Economics

RESEARCH INTERESTS

Antitrust and Regulation, Technology Policy, Political Economics, Political Economy of Law

MEMBERSHIP ON BOARDS AND COMMITTEES

President's Task Force on Communications Policy (CEA Staff Representative), 1967-68
President's Task Force on Suburban Problems, 1968
President's Committee on Urban Housing, 1968
President's Task Force on Public Broadcasting, 1968
Department of Commerce Technical Advisory Board Panel on Venture Capital, 1968-69
Committee on the Multiple Uses of the Coastal Zone, National Council on Marine Resources and Engineering, 1968
Secretary, President's Interagency Task Force on Income Maintenance, 1968
Task Force on Application of Economic Analysis to Transportation Problems, National Research Council, 1970-73
Committee on Technological Forecasting on Behalf of the Environment, Office of Science and Technology, 1970-71
Board of Economic Advisers, Public Interest Economics Foundation, 1974-84
Executive Committee, Caltech Environmental Quality Laboratory, 1970-71
Faculty Board, Caltech, 1974-76
Advisory Commission on Regulatory Reform, Senate Committee on Government Operations, 1975-77
Chair, Fourth Annual Telecommunications Policy Research Conference, 1975-76
Committee on Satellite Communications, National Academy of Sciences, 1975-76
Advisory Council, Jet Propulsion Laboratory, 1976-82
Chair, Committee to Monitor the Desegregation Plan of the Los Angeles Unified School District, Los Angeles Superior Court, 1978-79
Advisory Council, National Aeronautics and Space Administration, 1978-81
Advisory Council, National Science Foundation, 1978-89
Board of Advisers, National Institute of Economics and Law, 1978-84
Research Advisory Board, Committee for Economic Development, 1979-82
President's Commission for a National Agenda for the Eighties, 1980
Board of Directors, Economists, Inc., 1981-
Review Panel, NSF Regulation and Public Policy Program, 1981-84
Board of Editors, Journal of Economic Literature, 1981-90
Advisory Board, Solar Energy Research Institute, 1982-91
Board of Directors, Cornell Pelcovits and Brenner, Inc., 1982-1988

Chair, Advisory Panel on Information Technology R&D, Office of Technology Assessment, 1983-84
 Supervisory Board of Editors, Information Economics and Policy, 1982-88
 Advisory Committee on Integrated Environmental Management Program, Environmental Protection Agency, 1983-85
 Commission on Behavioral and Social Sciences and Education, National Research Council, 1984-90
 Advisory Panel, NSF Policy Research and Analysis Division, 1984
 Director, Program on Regulatory Policy, Stanford Institute for Economic Policy Research, 1984-
 Panel on Clean Air, Science Advisory Board, Environmental Protection Agency, 1985-86
 Board of Editors, Review of Economics and Statistics, 1985-2002
 Contributing Editor, Regulation, 1986-93
 Energy Research Advisory Board, Department of Energy, 1986-89
 President & Chairman of the Board, Telecommunications Policy Research Foundation, 1986-87
 Coordinating Editor, Information Economics and Policy, 1988-92
 Board of Directors, International Telecommunications Society, 1988-92
 Advisory Board of Editors, Journal of Risk and Uncertainty, 1988-
 Acid Rain Advisory Committee, Environmental Protection Agency, 1990-91
 Secretary of Energy Advisory Board, 1990-95
 International Board of Editors, International Journal of the Economics of Business, 1993-
 Faculty Senate, Stanford University, 1993-95, 98-02, 04-06
 California Council on Science and Technology, 1995-2001
 Panel on Universities, President's Committee of Advisors on Science and Technology, 1996
 Committee on Intellectual Property and the Information Infrastructure, National Research Council, 1997-9
 Board of Editors, Journal of Sports Economics, 1999-
 Board of Associate Editors, Economics of Governance, 1999-
 Board of Advisors, American Antitrust Institute, 2000-
 Board on Science, Technology and Economic Policy, National Research Council, 2000-2006
 Committee on Universal Postal Service, National Research Council, 2008

SPONSORED RESEARCH

"Opinions of Policemen." International Association of Chiefs of Police, 1969
 "Studies in the Regulation of Economic Activity." Brookings Institution and Ford Foundation, 1970- 3
 "Government Policies and Technological Innovation." National Science Foundation National R&D Assessment Program, 1973-4
 "The Social Consequences of Earthquake Prediction," National Aeronautics and Space Administration, 1974-6
 "Nuclear Safety Regulation." National Science Foundation RANN Program, 1975-7
 "The Public Television Station Program Cooperative." National Science Foundation RANN Program, 1975-7
 "The Station Allocation Game." Federal Communications Commission, 1977
 "Energy Policy Studies." Various donors, 1978-84
 "Economics of Oil Leasing" and "Issues in Utility Pricing." Department of Energy, 1978-9
 "The Economics of Boxing, Wrestling and Karate." California Athletic Commission, 1978
 "Implementing Tradable Emissions Permits." California Air Resources Board, 1979-82
 "Social Science and Regulatory Policy." National Science Foundation, 1980-2
 "The Political Economy of Public Policy." National Science Foundation and Center for Economic Policy Research, Stanford University, 1983-4
 "SIEPR Program on Regulatory Policy." various donors, 1987-
 "The Economics of Research Universities and Scholarly Communication." Brown Center for Education Policy, Brookings Institution, 1995-6
 "Coordination of Regulatory Reform," Organization for Economic Cooperation and Development, 1996
 "The Future of the Research University," Carnegie Foundation, 1996
 "SCID Program in Economic Policy Reform," Various donors, 2002-06

Membership on Committees and Boards, cont'd

CONSULTING

Special Assistant to the President, Ford Foundation, 1969
Space Technology Applications, Jet Propulsion Laboratory, 1969
Panel on the Abatement of Particulate Emissions, National Research Council, 1971
Sloan Commission on Cable Communications, 1971
President's Commission on Government Procurement, 1971
Senate Subcommittee on Antitrust and Monopoly, 1971-72
MCI, Inc., 1972-73, 1983, 1986
National Science Foundation, 1973, 1975
Department of Justice, Antitrust Division, 1974-77, 1979-81, 1993-97
Internal Revenue Service, 1976-77
RAND Corporation, 1974-82
Los Angeles Lakers, 1974-75
National Football League Players Association, 1974-76, 1987-93, 2008, 2010-
Office of Telecommunications Policy, 1975-77
National Basketball Association Players Association, 1975-76, 1987-88, 1994
Naval Ordnance Test Station, 1975
Commission on Law and the Economy, American Bar Association, 1977-78
Aspen Institute Program on Communications and Society, 1977
National Commission on Electronic Funds Transfer, 1977
Business Round Table, 1978
Federal Communications Commission, 1977-81
Food and Drug Administration, 1978
Carnegie Commission on the Future of Public Broadcasting, 1978
Department of Energy, 1979
Office of Technology Assessment, 1980
Kerr-McGee Corporation, 1980
CBS, Inc. 1982-83
Environmental Protection Agency, 1982-83
Showtime/The Movie Channel, 1983, 1985
Harlequin Books, 1984
Lake Huron Broadcasting, 1984
National Collegiate Athletics Association, 1984
National Medical Enterprises, 1985, 1987-88
Camellia City Telecasters, 1985-86
Brown and Root, Inc., 1985-86
McDermott, Inc., 1985-86
Major League Baseball Players Association, 1985, 1994
United Cable Television and American Television and Communications, 1985
United States Football League, 1985-86
City of Anaheim, 1986
Technicolor, 1986
Metro-Mobile, 1986-89
Hewlett-Packard, 1986-1990, 1991
Echostar, 1987, 1994-95, 2002-03, 2004-05
Continental Airlines, 1987-88
Home Box Office, 1988-89
Bell South Cellular, 1989
Western Union, 1989
Minnesota Twins, 1989
Northwest Airlines, 1989
Pepsico, 1989
Yellow Phone, 1989-91
Dialog, 1990-91

Consulting, cont'd

California Public Utilities Commission, 1989-90
American Newspaper Publishers Association, 1990
Humana, 1990-91
Powell, Goldstein, Frazer and Murphy, 1990-93
South Coast Air Quality Management District, 1990-91
Federal Trade Commission, 1990-91, 2010-
Delta Airlines, 1991
California Cable Television Association, 1991
Bureau of Competition Policy, Government of Canada, 1991
R&D Business Systems, *et al.* 1991-95
International Entertainment Group, 1992-93
Nike, Inc., 1992
World Bank, 1992-
Gemini, Inc. 1992-94
Servicetrends, Inc., 1993-94
William Sullivan, 1993-95
Sure Safe Industries, 1993
U. S. Department of Justice, Civil Division 1994-95
Kopies, Inc., *et al.* 1995-1999
Telecom Technical Services, *et al.*, 1995-1999
Digital Distribution, Inc.. 1996-1999
Silvey, *et al.*, 1996-2000
Aguillar, *et al.* 1996-2000
Wadley Medical Center, 1997-2001
Oakland Raiders, 1997-2000
Major League Soccer Players Association, 1997-2000
Class Plaintiffs, Brand Name Prescription Drugs Litigation, 1998-9
Class Plaintiffs, Compact Disc Litigation, 1999-2003
Class Plaintiffs, State Microsoft Antitrust Litigation (California, Iowa, Minnesota, New York), 2000-2007
Kingray, 2000
Napster, 2000-2
Metropolitan Intercollegiate Basketball Association, 2002-5
Congressional Budget Office, 2002
Pioneer and Scientific Atlanta, 2002-3
Lenscrafters, 2003-4, 2009-12
Seven Network, 2003-7
Sports Car Clubs of America, 2003-05
Intertainer, 2003-05
Class Plaintiffs, DRAM Antitrust Litigation 2005-7
Class Plaintiffs, Honeywell Antitrust Litigation, 2005-
Class Plaintiffs, Tableware Antitrust Litigation, 2005-7
Class Plaintiffs, *White, et al., v. NCAA*, 2006-8
Sirius Satellite Radio and XM Satellite Radio, 2006-7
Class Plaintiffs, Cartier Antitrust Litigation, 2006-7
Monte Carlo Country Club and Socit Mongasque pour l'Exploitation du Tournoi de Tennis, 2007
Pearle Vision, Inc., 2007-8
Class Plaintiffs, Apple iTunes/iPod Antitrust Litigation, 2007-
Class Plaintiffs, SRAM Antitrust Litigation, 2007-9
Fair Isaac, 2007-9
Houston Baptist University, 2008.
U. S. Department of Justice, U. S. Attorney's Office, San Francisco, 2008-9
Novell, 2008-11
GlaxoSmithKline, 2008-11
Class Plaintiffs, Flash Memory Antitrust Litigation, 2008-10
MobiTV, 2009-10

Consulting, cont'd

AT&T, 2009-10
Verizon, 2009-10
Ericsson, 2009-10
Kaleidescape, 2011-12
Class Plaintiffs, Text Messaging Antitrust Litigation, 2011-
Class Plaintiffs, California Automobile Insurance Antitrust Litigation, 2011-
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APPENDIX B

APPENDIX B
Documents/Data Considered By Professor Roger G. Noll and/or Economists Inc.

Document Title

1. Order Granting in Part Defendant's Motion for Judgment on the Pleadings; Ordering Supplemental Briefing
2. Order Granting Defendant's Motion for Judgment on the Pleadings As to the First Cause of Action for Violations of Section 1 of the Sherman Act and The Fifth Cause of Action for Violations of the Cartwright Act
3. Order Decertifying Classes Without Prejudice to Being Renewed; Inviting Further Motions
4. Defendant's Motion for Decertification of Rule 23(B)(3) Class
5. Expert Report of Dr. Michelle M. Burtis
6. Declaration of Michael Scott in Support of Defendant's Motion for Decertification of Rule 23(B)(3) Class
7. Plaintiffs' Memorandum in Opposition to Defendant's Motion for Decertification of Rule 23(b)(3) Class
8. Reply Declaration of Roger G. Noll
9. Declaration of Thomas R. Merrick in Support of Plaintiffs' Memorandum in Opposition to Defendant's Motion for Decertification of Rule 23(b)(3) Class
10. Defendant's Reply In Support of Motion for Decertification of Rule 23(B)(3) Class
11. Reply Expert Report of Dr. Michelle M. Burtis
12. Declaration of David C. Kiernan in Support of Reply on Motion for Decertification of Rule 23(B)(3) Class
13. Amended Consolidated Complaint for Violations of Sherman Antitrust Act, Clayton Act, Cartwright Act, California Unfair Competition Law, Consumers Legal Remedies Act, And California Common Law of Monopolization
14. Defendant Apple Inc.'s First Amended Answer and Defenses to Plaintiffs' Amended Consolidated Complaint
15. Order Granting in Part and Denying in Part Defendant's Motion to Dismiss; Denying as Premature Defendant's Motion for Summary Judgment; Granting Indirect Purchaser Plaintiff Leave to File an Amended Complaint
16. Apple's Motion to Dismiss or, Alternatively, For Summary Judgment
17. Declaration of Michael Scott in Support of Apple's Motion to Dismiss or, Alternatively, For Summary Judgment
18. Declaration of Jeffrey Robbin in Support of Defendant's Motion to Dismiss or in the Alternative Motion For Summary Judgment
19. Plaintiffs' Memorandum in Opposition to Apple's Motion to Dismiss or, Alternatively, For Summary Judgment
20. Declaration of Thomas R. Merrick in Support of Plaintiffs' Memorandum in Opposition to Apple's Motion to Dismiss or, Alternatively, For Summary Judgment
21. Declaration of Paula M. Roach Pursuant to Rule 56(f) of the Federal Rules of Civil Procedure in Support of Plaintiffs' Opposition to Apple's Motion to Dismiss or, Alternatively, For Summary Judgment

APPENDIX B

Documents/Data Considered By Professor Roger G. Noll and/or Economists Inc.

22. Apple's Reply in Support of Motion to Dismiss or, Alternatively, For Summary Judgment
23. Declaration of David C. Kiernan in Support of Apple's Reply in Support of Motion to Dismiss or, Alternatively, For Summary Judgment
24. Plaintiffs' Reply in Support of Their Motion for Additional Discovery Pursuant to Rule 56(f)
25. Declaration of Thomas R. Merrick in Support of Motion for Additional Discovery Pursuant to Rule 56(f)
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28. Defendant Apple Inc.'s Response to Plaintiffs' Amended First Set of Requests for Production of Documents
29. Defendant's Response to Plaintiffs' Second Set of Requests for Production of Documents
30. Defendant's Response to Plaintiffs' Third Set of Requests for Production of Documents
31. Defendant's Responses to Plaintiffs' First Set of Interrogatories Directed at Defendant Apple Computer, Inc.
32. Defendant Apple Inc.'s First Amended Objections and Answers to Plaintiffs' Amended First Set of Interrogatories
33. Defendant Apple Inc.'s Supplemental Objections and Answers to Plaintiffs' Amended First Set of Interrogatories
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100. Deposition Transcript of Jeffrey L Robbin, taken December 3, 2010 and Exhibits 1-20
101. Deposition Transcript of Augustin J. Farrugia, taken December 8, 2010 and Exhibits 21-31
102. Deposition Transcript of David K. Heller, taken December 15, 2010 and Exhibits 32- 51
103. Deposition Transcript of Arthur Rangel, taken December 17, 2010 and Exhibits 80-94
104. Deposition Transcript of Eddy Cue, taken December 17, 2010 and Exhibits 52-74
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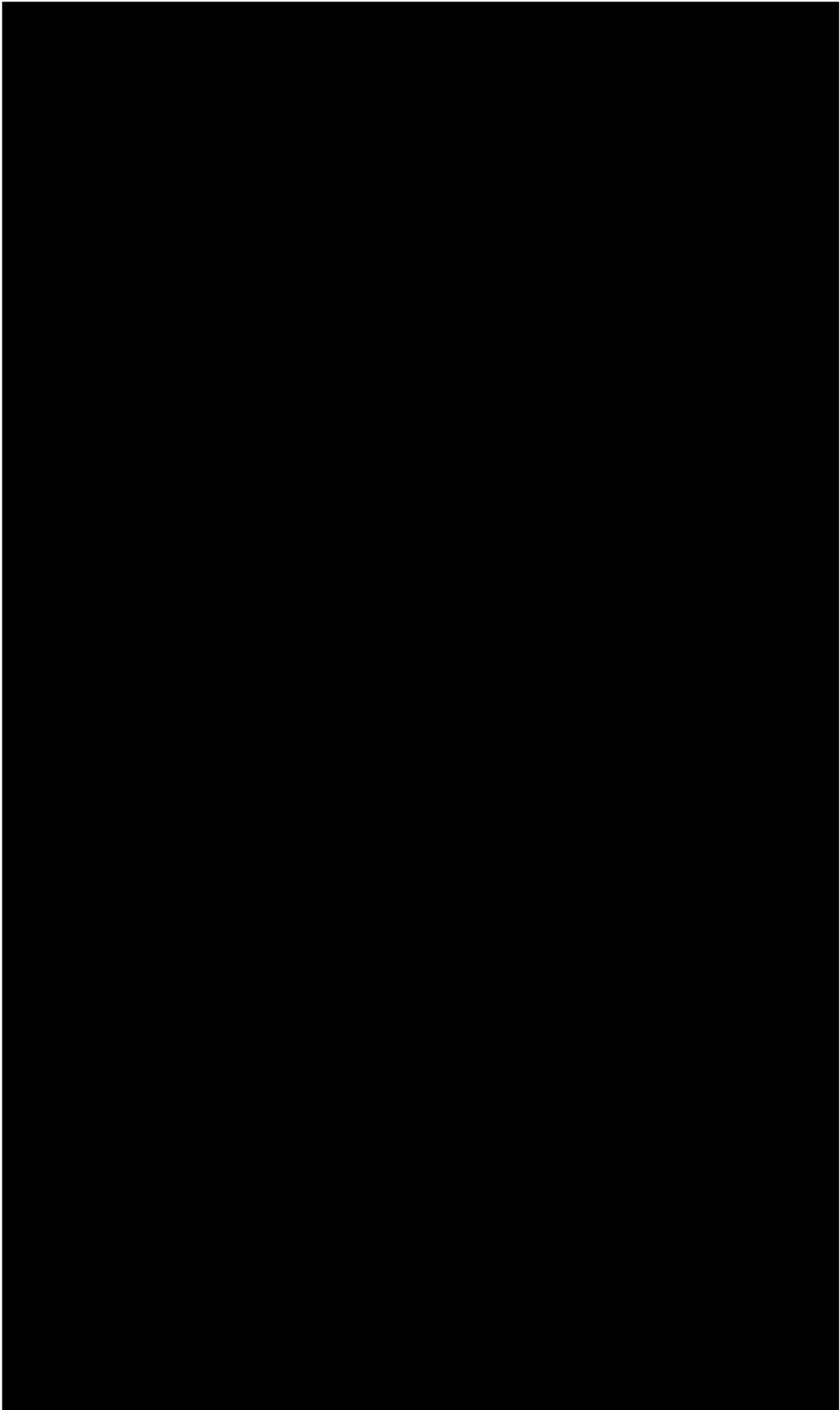
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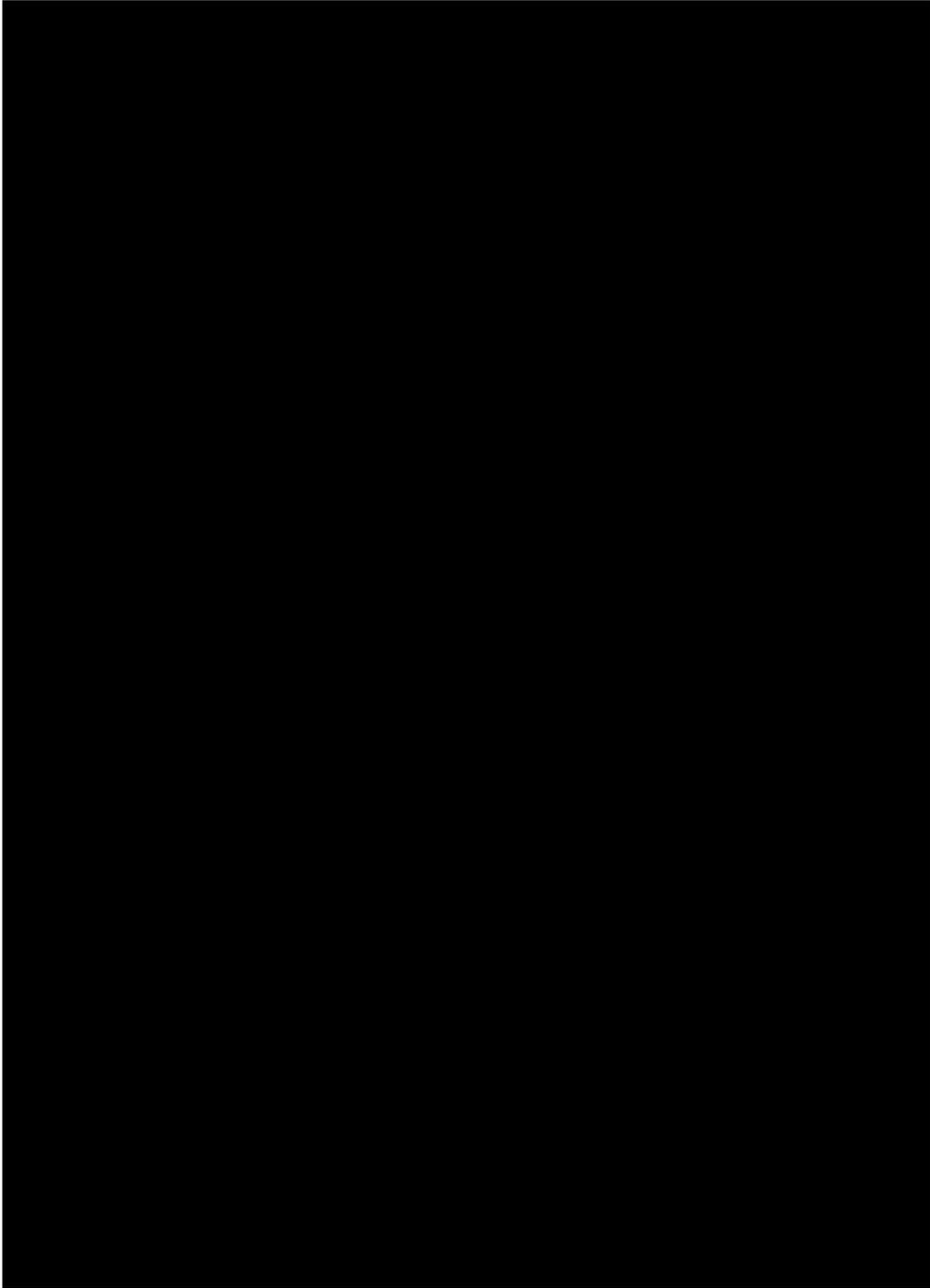
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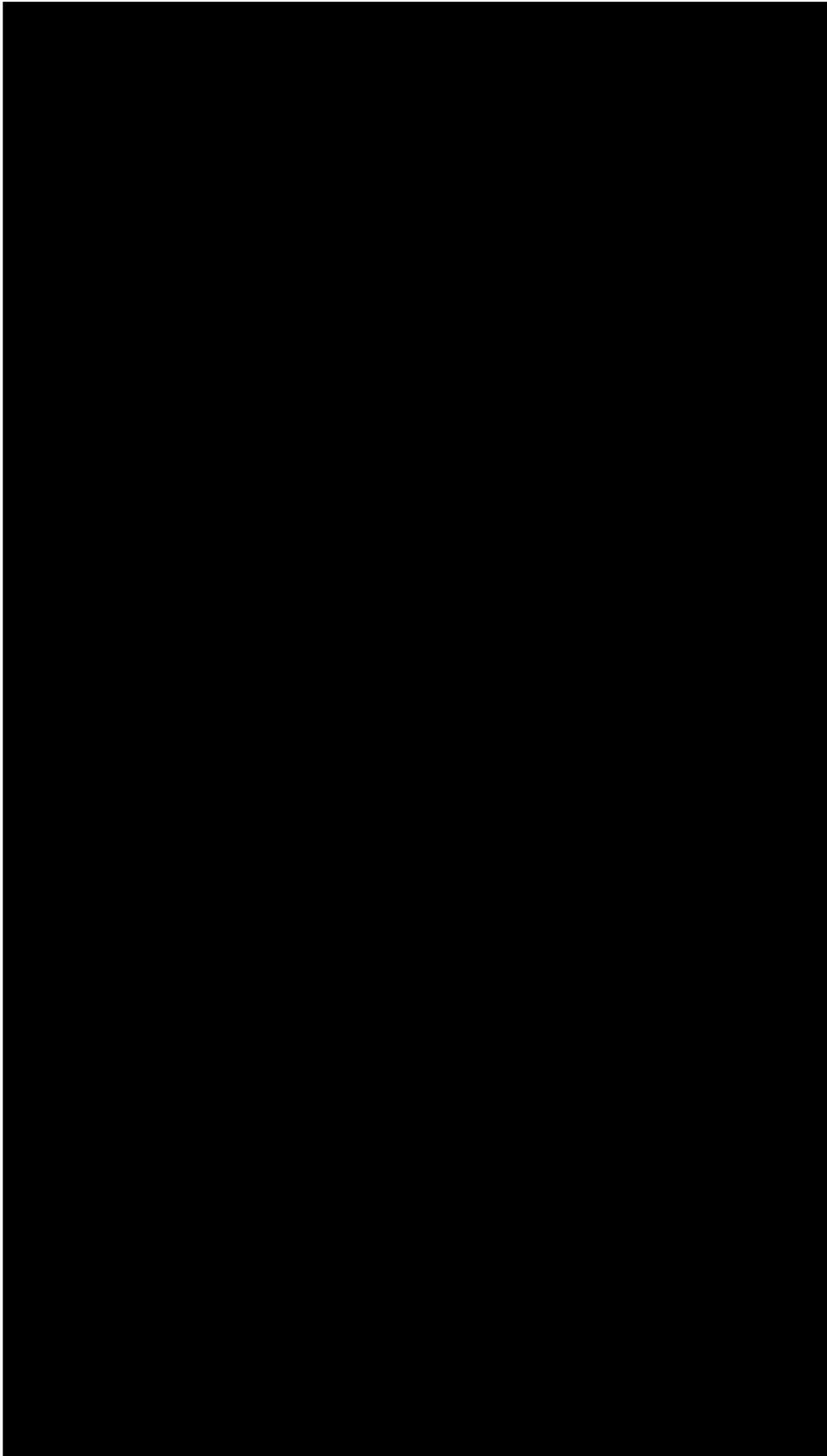
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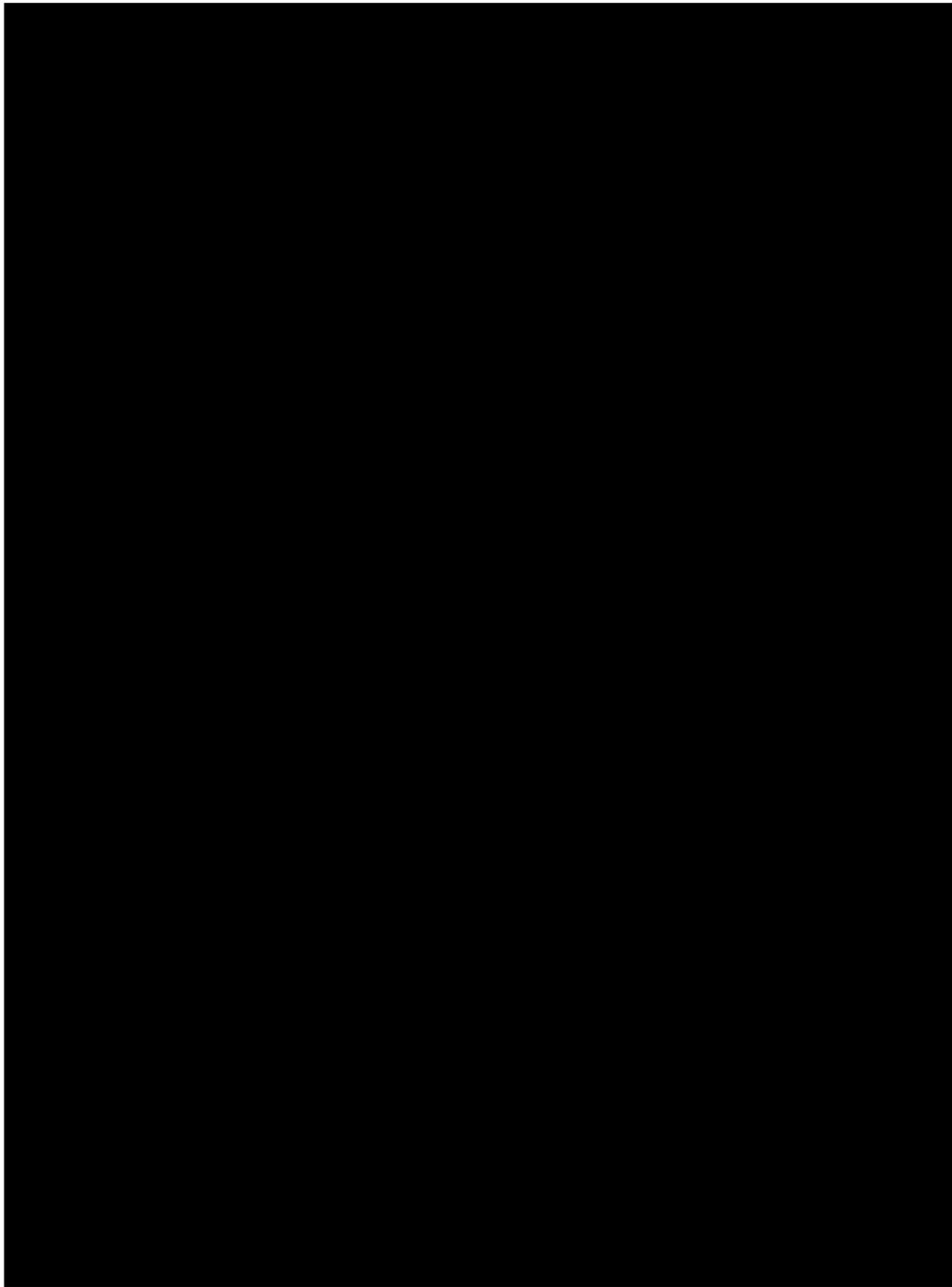
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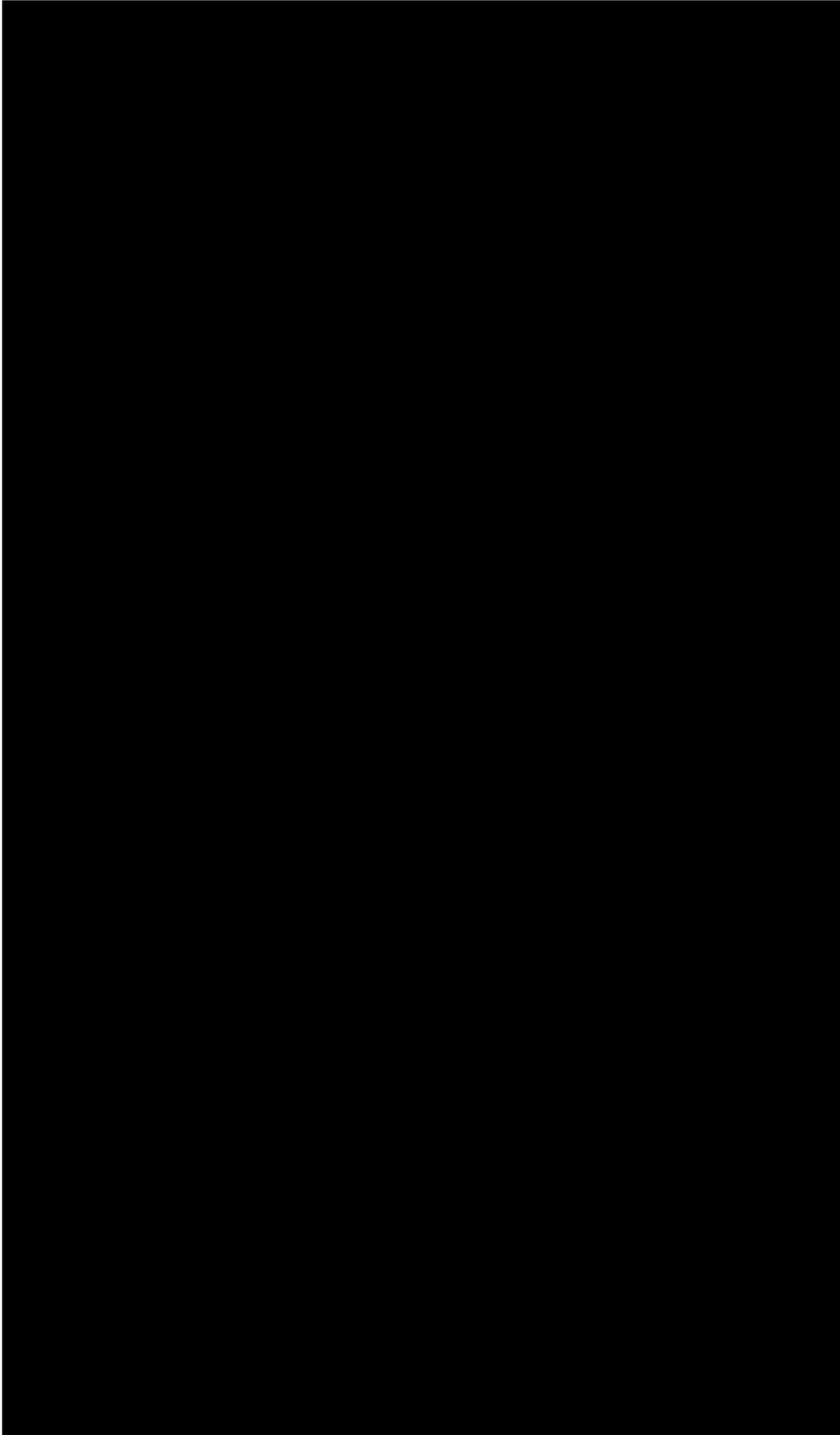




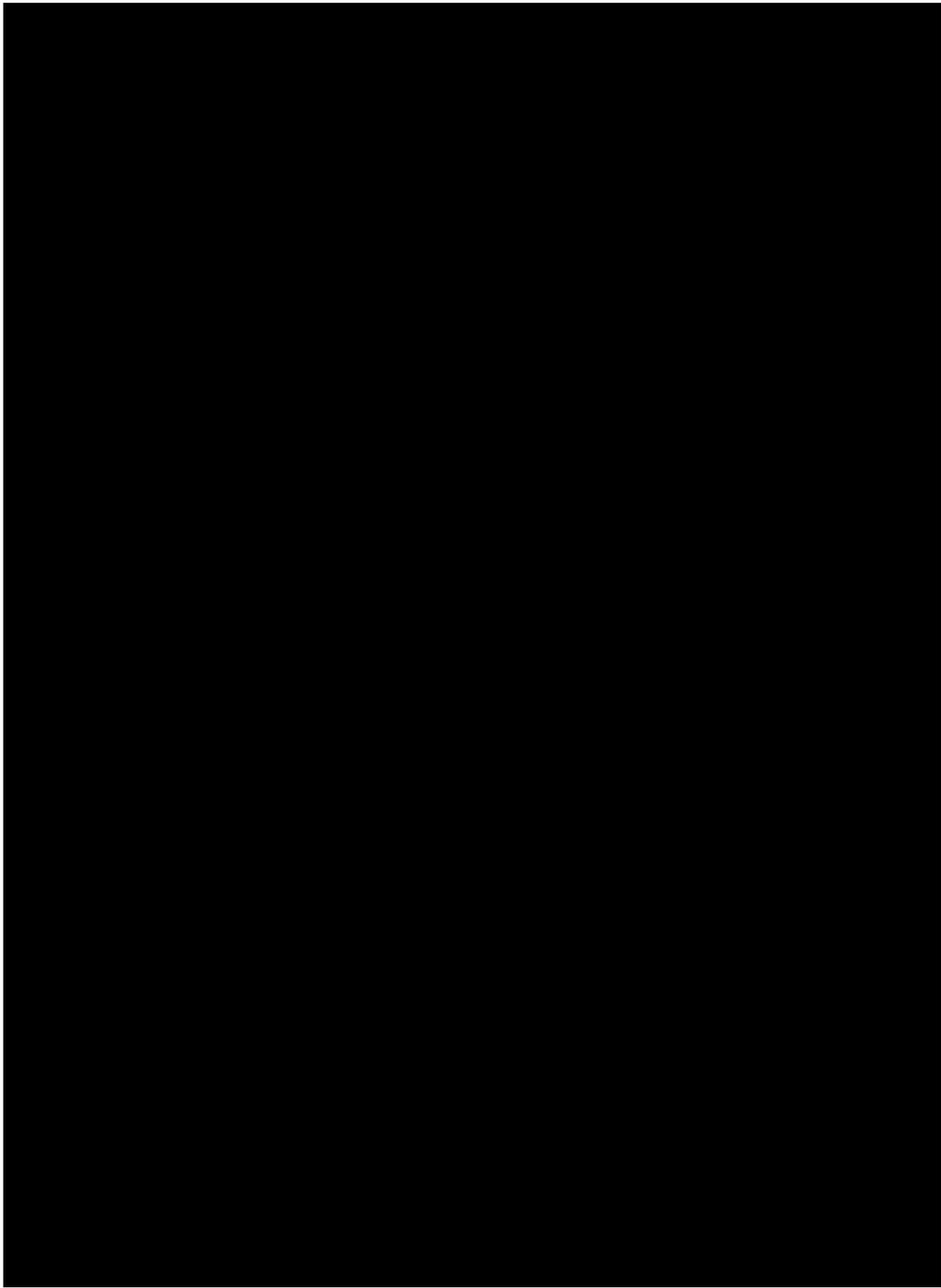


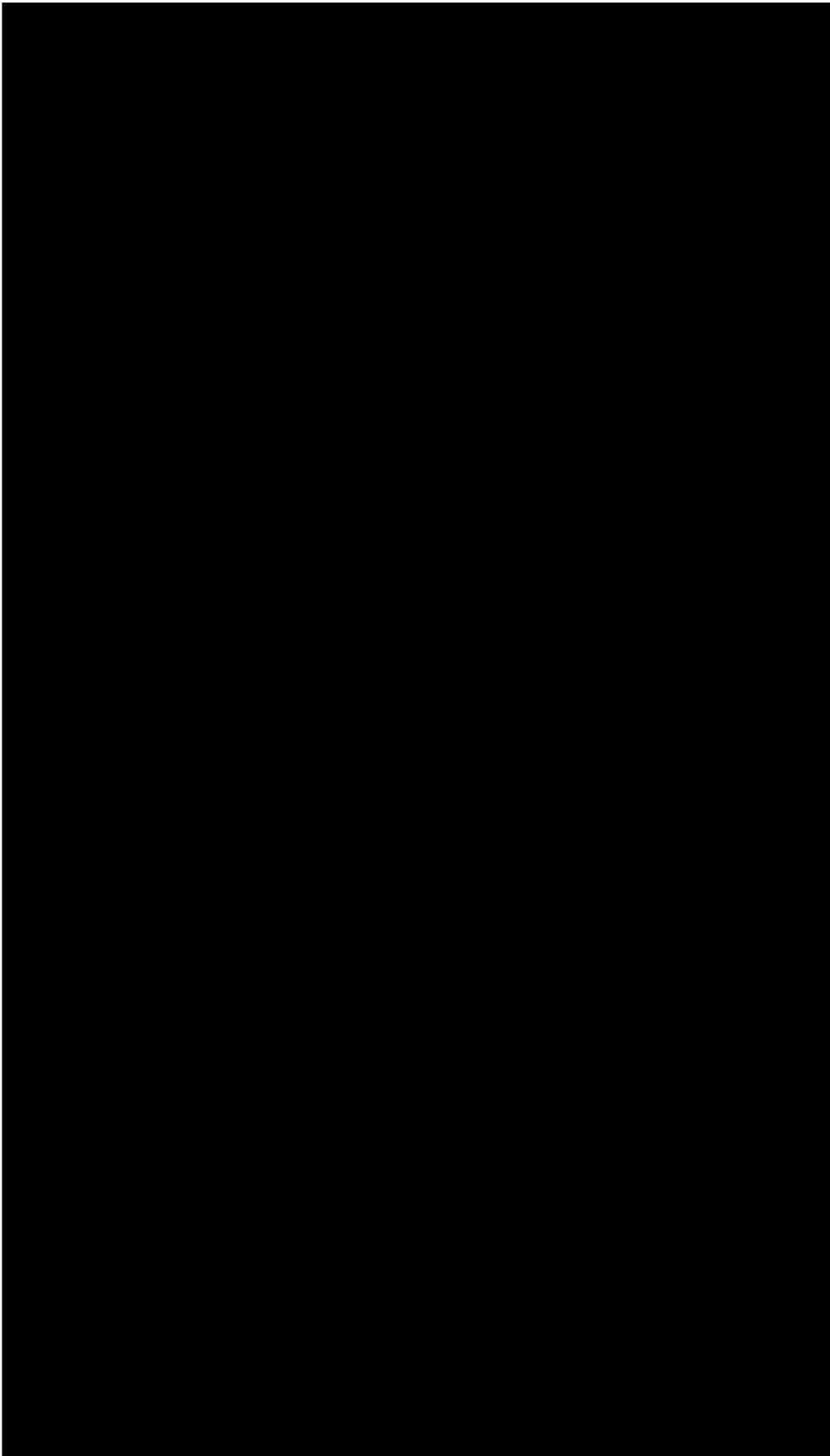
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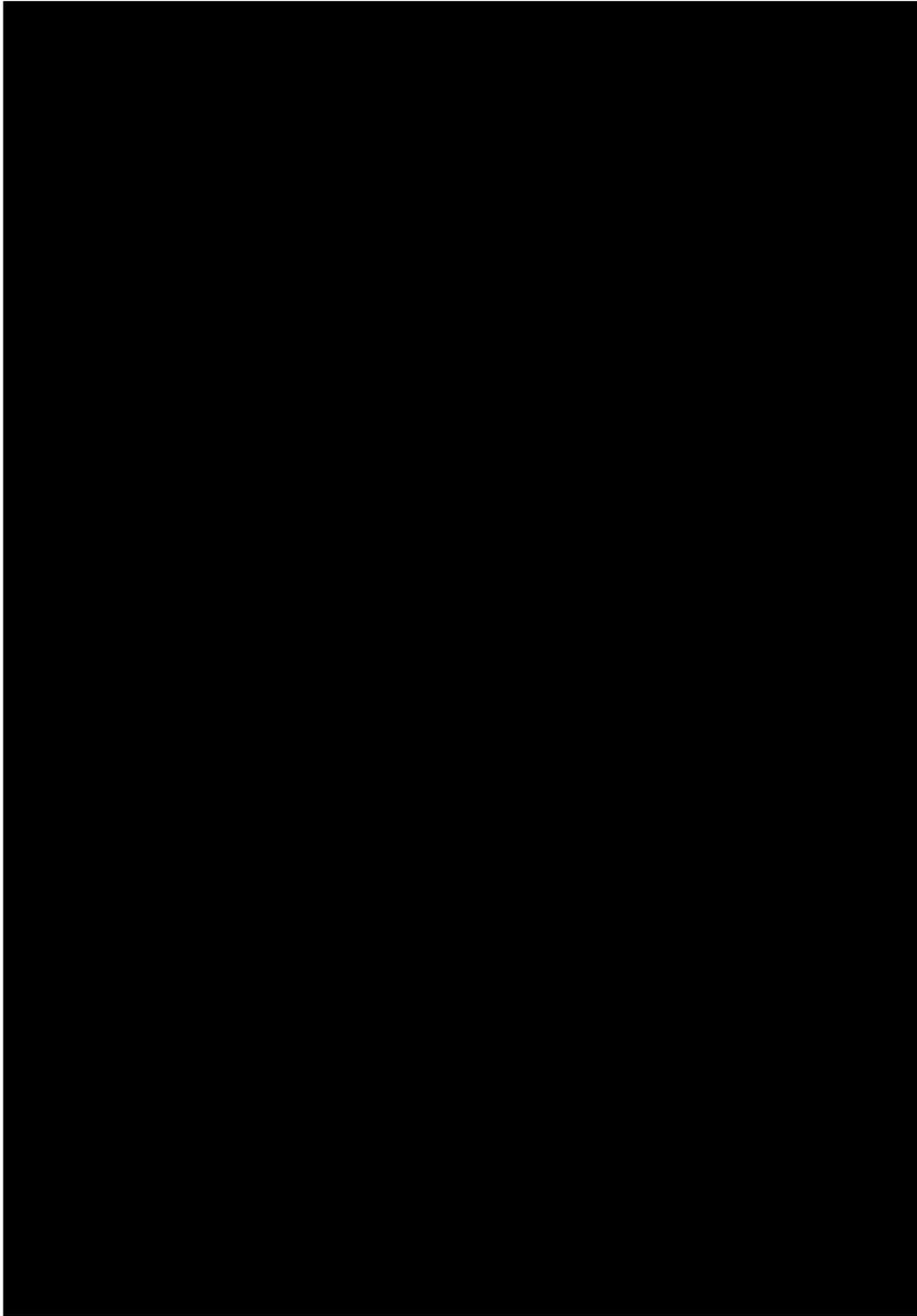


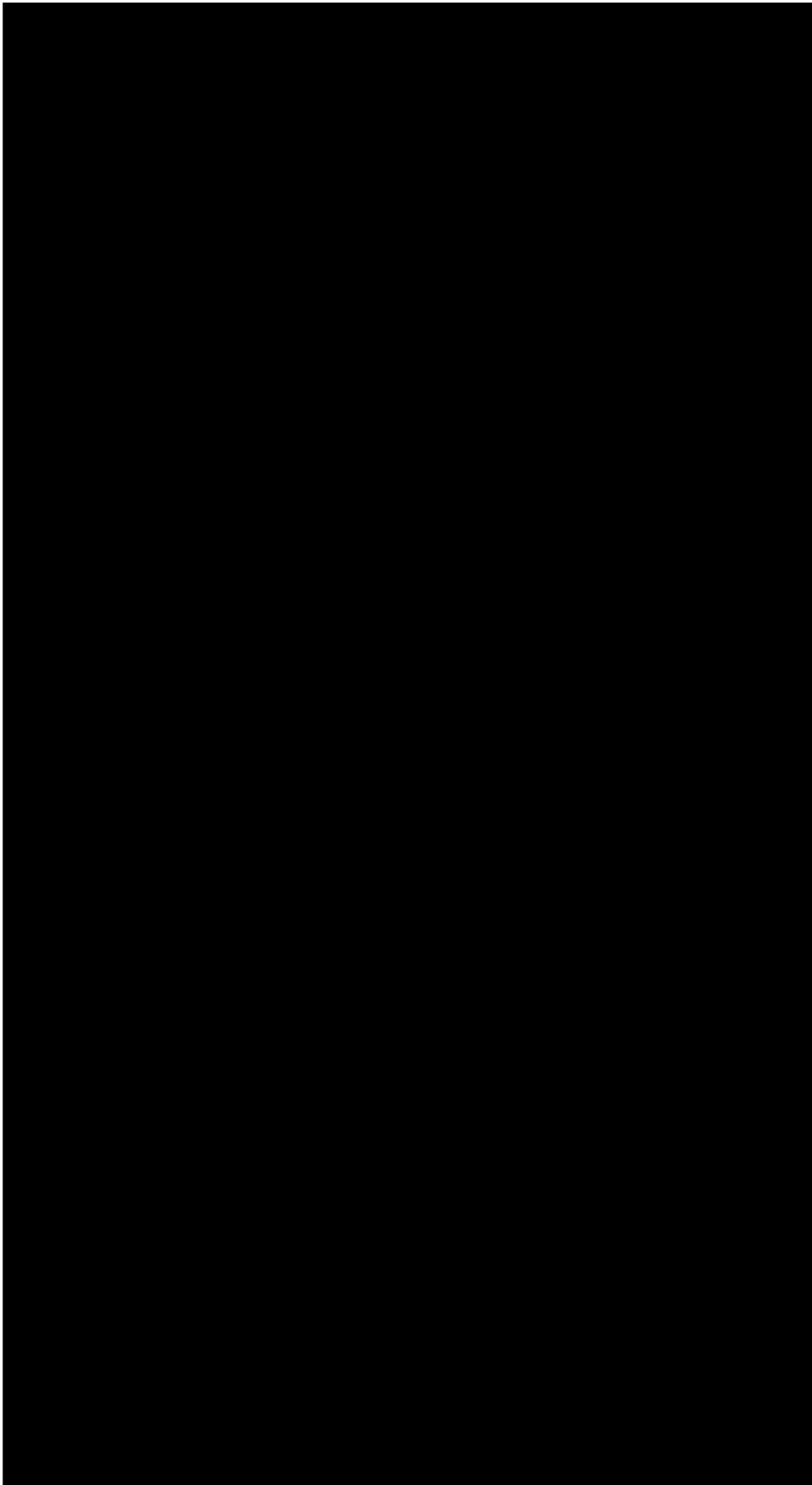
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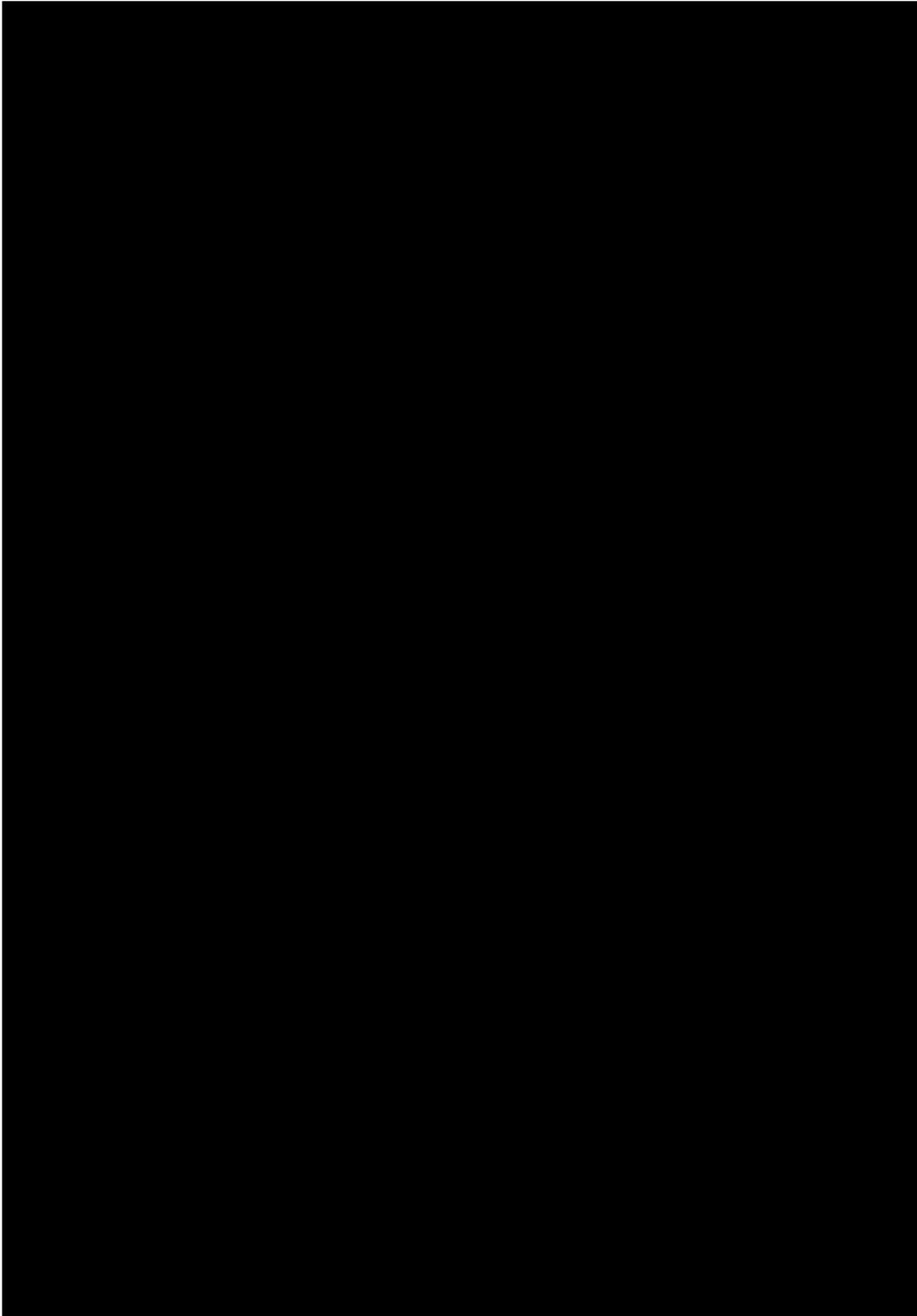


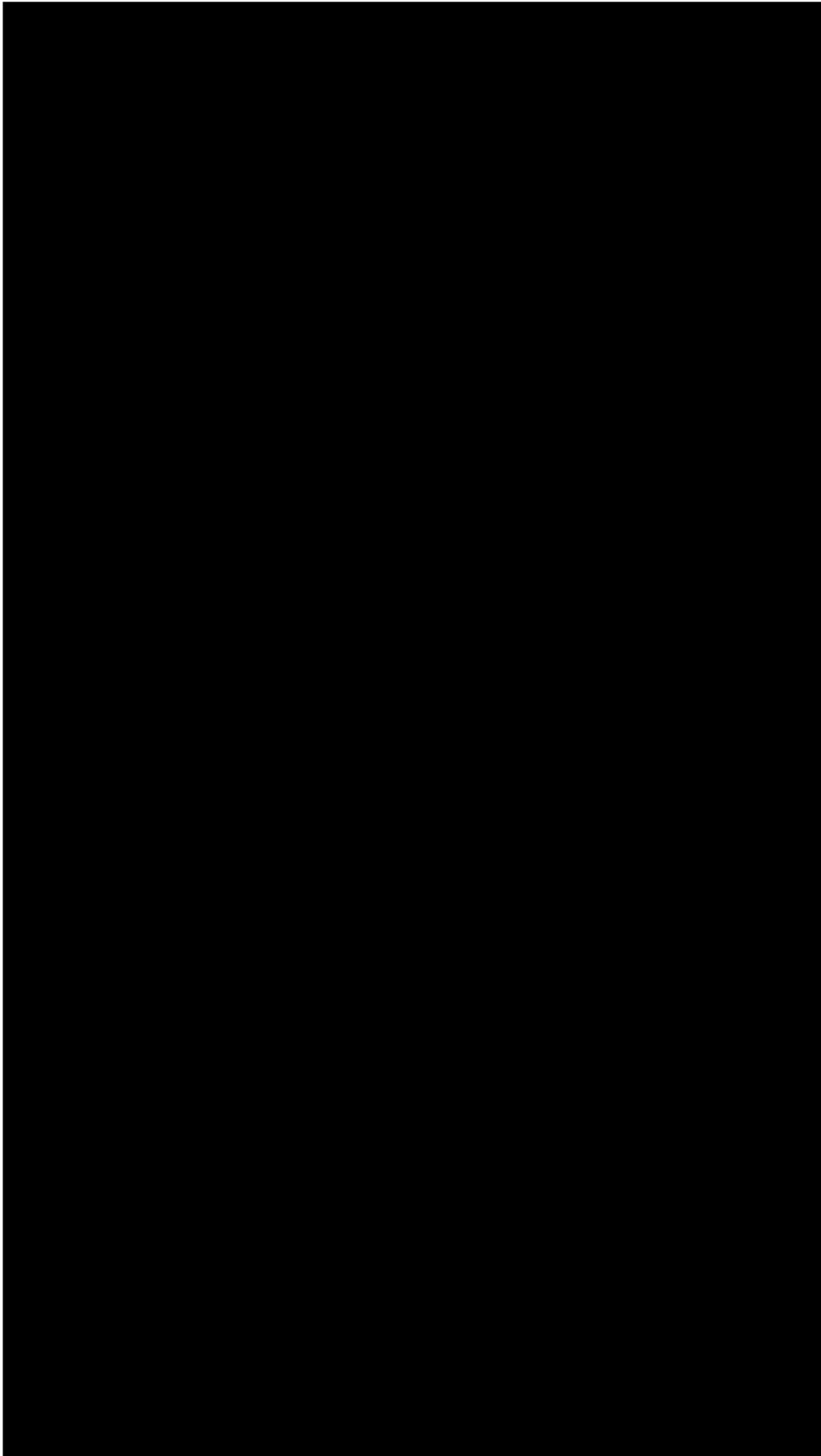
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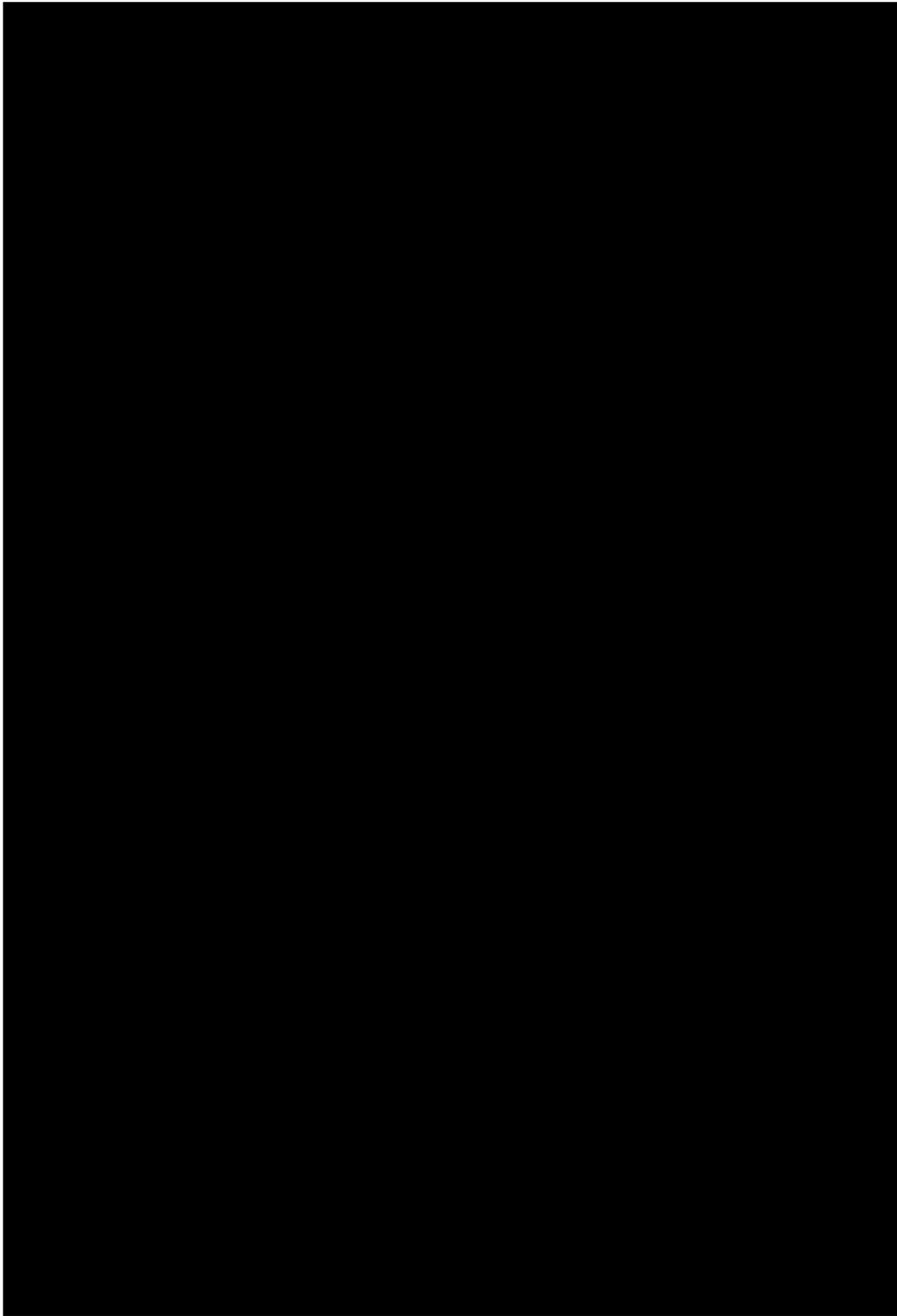


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DECLARATION OF SERVICE BY MAIL AND E-MAIL

I, the undersigned, declare:

1. That declarant is and was, at all times herein mentioned, a citizen of the United States and a resident of the County of San Diego, over the age of 18 years, and not a party to or interested party in the within action; that declarant's business address is 655 West Broadway, Suite 1900, San Diego, California 92101.

2. That on April 3, 2013, declarant caused to be served DECLARATION OF ROGER G. NOLL ON LIABILITY AND DAMAGES by depositing a true copy thereof in a United States mailbox at San Diego, California in a sealed envelope with postage thereon fully prepaid and addressed to the parties listed on the attached Service List.

3. That there is a regular communication by mail between the place of mailing and the places so addressed.

4. Also on April 3, 2013, I served the attached DECLARATION OF ROGER G. NOLL ON LIABILITY AND DAMAGES on the parties in the within action by e-mail addressed as follows:

Counsel for Defendants:

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Robert Mittelstaedt	Jones Day	ramittelstaedt@jonesday.com
David Kiernan	Jones Day	dkiernan@jonesday.com
Caroline Mitchell	Jones Day	cnmitchell@jonesday.com

I declare under penalty of perjury that the foregoing is true and correct. Executed on April 3, 2013, at San Diego, California.



HEATHER S. BROWN

APPLE TYING

Service List - 4/3/2013 (06-0171)

Page 1 of 1

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APPLE'S (PROPOSED) REDACTIONS

EXHIBIT 2
[Filed Under Seal]

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
OAKLAND DIVISION

APPLE IPOD ITUNES ANTI-TRUST
LITIGATION

Lead Case No. C-05-00037-YGR

**REBUTTAL DECLARATION OF ROGER G. NOLL
ON LIABILITY AND DAMAGES**

My name is Roger G. Noll, and previously I have submitted eight declarations in this proceeding.¹ My previous declarations contain my career history and qualifications. My current *curriculum vita*, which has an up-to-date list of my publications, is attached to this declaration as Appendix A.

Since submitting my report on liability and damages, I have submitted expert reports and been deposed in the following new matters.

In re Application of Pandora Media, Inc. Related to U.S. vs. ASCAP (U.S. District Court, New York City);

City of San Jose, et al., vs. Office of the Commissioner of Baseball, et al. (U.S. District Court, San Jose); and

In re Electronic Books Antitrust Litigation (U.S. District Court, New York City).

¹ *Declaration of Roger G. Noll* (July 15, 2008), *Reply Declaration of Roger G. Noll* (October 19, 2009), *Declaration of Roger G. Noll* (January 18, 2011), *Reply Declaration of Roger G. Noll* (March 28, 2011), *Supplemental Declaration of Roger G. Noll* (July 18, 2011), *Second Supplemental Declaration of Roger G. Noll* (September 23, 2011), *Declaration of Roger G. Noll on Liability and Damages* (April 13, 2013; henceforth *Noll Merits Report*), and *Corrections to the Declaration of Roger G. Noll on Liability and Damages* (May 13, 2013; henceforth, *Noll Corrections Report*).

ASSIGNMENT

Attorneys for the class plaintiffs in this litigation have asked me to review the *Expert Report of Kevin M. Murphy* (henceforth *Murphy Report*) and the *Expert Report of Robert H. Topel* (henceforth *Topel Report*) that were submitted on behalf of defendant Apple, Inc., to determine whether any of the evidence and analysis in these reports causes me to change the conclusions in the *Noll Merits Report*, as amended in the *Noll Corrections Report*. The attorneys for the class plaintiffs also have asked me to re-estimate the damages regressions in the *Noll Corrections Report* to take into account new information on the iPod models in which iTunes 7.0 was used. In undertaking this assignment, I have read the expert reports and depositions of Professors Murphy and Topel and other documents and publications that are referenced in the footnotes of this declaration. In preparing this report I have been assisted by the staff of Economists, Inc.

SUMMARY AND CONCLUSIONS

This declaration reports new regression equations for demonstrating class-wide harm and calculating damages. The most important source of differences between the new regressions and the regressions that were reported in the *Noll Merits Report* is that the new regressions limit the effect of iTunes 7.0 to iPod models for which the features of iTunes 7.0 that disabled Harmony were enabled, according to information that Apple produced after the *Noll Merits Report* was submitted. (Throughout this report, I use the term “iPod model” to refer to a class/generation/family of iPod.)

The *Murphy Report* and the *Topel Report* make numerous criticisms of the analysis of both liability and damages in my previous reports. Their most important

complaint is that the regressions that I used in the *Noll Merits Report* and the *Noll Corrections Report* contain numerous errors in specifying and estimating the equations that cause the results of those regressions to be unreliable, and that correcting these errors causes the estimate of anticompetitive injury and damages to class members to be zero.

After reviewing these reports and undertaking further econometric analysis, I have concluded that the criticisms by defendant's experts fall into two categories. The first consists of criticisms that have some basis in economics but that overstate the importance of their criticisms. In these cases, regardless of whether I agree that the criticisms warrant changing the procedures that I used, I have adopted the changes that Professors Murphy and Topel propose, and find that these changes have only a small effect on the amount of damages that is calculated from the regression equations. The second category consists of criticisms that have no basis in economics and so do not warrant changes in the analysis and methods in my previous reports.

Liability Issues

The *Murphy Report* contains several criticisms about my analysis of market definition and market power. These criticisms are not based on a valid economic analysis of either issue, and so do not cause me to change any of the arguments and analysis in the *Noll Merits Report*.

Professor Murphy sets forth reasons that he believes that closed systems (“walled gardens”) like the Apple combinations of iPods, iTunes media player software, and the iTunes Store (iTS) are superior to a system composed of complementary products that are purchased from different vendors. While Professor Murphy does not provide any

economic analysis to support this assessment, even if it were true Professor Murphy does not explain why disabling the use of competing products is necessary or beneficial to consumers if technologies that create lock-in are also more expensive because lock-in diminishes competition.

Professor Murphy also argues that a seller of all complementary products will charge lower, not higher, prices. This claim is incorrect because it assumes that the seller of each component enjoys unilateral market power and overlooks the effect of lock-in. If a technology locks customers in to buying all components from a single seller, competition in each component is reduced, and reduced competition can cause the price of each component to be higher, not lower.

Professor Murphy argues that digital downloads are not a properly defined market because consumers can obtain recordings in other ways, and that in any case this issue is irrelevant because the case is about lock-in. Regarding competition among types of recordings (CDs, illegal file sharing, on-demand streaming), Professor Murphy does not apply the methods of antitrust economics and offers no economic evidence to support the conclusion that other forms of recordings are as close competitive substitutes for iTunes as are other download sites. In addition, the claim that lock-in effects render market definition irrelevant is incorrect – one must still address which vendors of which products would be the most intense competitors for the reference product in the absence of lock-in.

Professor Murphy also opines that my analysis of the sources of Apple's market power in iPods – and the attribution of some of this market power to iTunes 7.0 – is incorrect because Apple also introduced iPods with new features when iTunes 7.0 was released. This criticism ignores the fact that the regression equation that explains prices

includes indicator variables for class, other product attributes, and time (to represent improved technology), which measure the effect of the characteristics of an iPod.

Criticisms Leading to Changes in Damages Calculations

Professors Murphy and Topel make four criticisms that lead me to make changes in the regression equations in the *Noll Merits Report*.

First, defendant's experts propose that quantity weights, rather than frequency weights, should be used to estimate the regression equations. While I agree that quantity weights produce better estimates of the standard errors of coefficients, the choice of a weighting procedure does not affect the regression coefficients and, in a large data set such as the Apple transactions records, leads to only minor changes in the results of the tests of the statistical significance of the coefficients on the independent variables in the regression equation. I show that this choice is inconsequential, but I use quantity weights in the revised damages model.

Second, Professors Murphy and Topel criticize my use of the logarithm of time rather than the scalar variable time in my regressions that use the logarithm of price as the dependent variable. I agree that there is no theoretical reason to prefer the logarithm of time to the scalar measure, so in the re-estimated damages equations I eliminate this difference between us by adopting the specification that is preferred by Professors Murphy and Topel.

Third, Professor Topel proposes that the appropriate date on which Apple's iTunes Store (iTTS) adopted a DRM-free format for music was January 6, 2009, instead of March 31, 2009, the date that was used in my previous reports. The facts are that Apple

made a transition to DRM-free music that began on January 6, but the significance of the initial change on January 6 and the speed of the complete transition to making DRM-free music available for all titles is unknown. Hence, a perfect measure of the availability of DRM-free music from January 6 to March 31, 2009, cannot be constructed. Because the issue of the best way to measure the importance of the introduction of DRM-free recordings on the iTunes Store (iTS) during the period between January 6 and March 31 is not of major importance, in the revised regressions I adopt Professor Topel's proposal and start the variable that indicates the availability of DRM-free music on January 6, rather than March 31.

Fourth, Professors Murphy and Topel argue that the indicator variable for Harmony, software that allowed iPod users to download recordings from Internet sites that used the RealNetworks DRM format, should distinguish between the first version, which was available from July 2004 until April 2005 and was disabled by iTunes 4.7, and the second version, which was introduced in April 2005 and worked around the disabling features of previous versions of the iTunes digital media player software starting with iTunes 4.7. In my new damages model, I have adopted this procedure.

Incorrect Criticisms that Require No Change

Professors Topel and Murphy make several criticisms that are not valid and that would reduce, not increase, the reliability of the regression analysis if they were adopted.

First, Professor Murphy and Topel argue that the indicator variable for iTunes 4.7 and subsequent versions of iTunes prior to the introduction of iTunes 7.0 should continue to take the value of one after this software was replaced by iTunes 7.0. This criticism

was directed at my original damages model, which was based on the assumption that iTunes 7.0 was used in all iPods that were sold after September 12, 2006. After I submitted the *Noll Merits Report*, Apple produced information that only some iPods that were sold after September 12, 2006, used iTunes 7.0. In the damages equations that are reported in this declaration, the indicator variable for iTunes 7.0 is set equal to one only for iPod models that used iTunes 7.0 or its successors. The variable for prior versions of iTunes that blocked Harmony, starting with iTunes 4.7, is now set to one after September 12, 2006, for iPods that did not use iTunes 7.0. I disagree with defendant's economic experts that the variable for software that disabled the first version of Harmony should remain set to one for iPod models that used iTunes 7.0 and its successors. These iPods did not contain both software programs. Apple chose to replace software that the court previously found to be legal with software that plaintiffs now contend was illegal. The regression equations that I use measure the effect of that change.

Second, Professor Murphy and Topel argue that, as a matter of economic theory, the effect of iTunes 7.0 on the prices of iPods would not occur immediately when iTunes 7.0 was introduced, but would occur gradually as customers who purchased these models became increasingly locked-in to Apple's technology. While the extent of lock-in does increase as a consumer buys more recordings that can be played only on iPods, this fact does not imply that, as a theoretical matter, the price differential would increase through time. The reason is that once iTunes 7.0 is launched, Apple no longer can compete for customers who have used a portable digital media player that plays downloads in the RealNetworks format, and so no longer has an incentive to try to attract those customers by cutting the prices of iPods that use software that effectively blocks Harmony.

Third, Professors Murphy and Topel claim that the regression is unreliable because it does not include every technical characteristic that differentiates models of iPods. This argument is incorrect. The goal of a hedonic price regression is to explain as much of the variance in prices of differentiated products as possible on the basis of the characteristics of each product. To achieve this goal requires adding variables that measure characteristics that differ among products up to the point that adding more such variables does not contribute significantly to explaining price differences. The reason that adding more characteristic variables to the price equations for iPods does not cause a meaningful increase in the explanatory power of the regression is that the variables for iPod class, capacity and cost that already are included in the regression already measure the effects of technical characteristics that are peculiar to a particular model. If the additional technical characteristics that Professors Murphy and Topel discuss are added to the equation, the effect is to cause extreme multicollinearity (i.e., a high correlation between separate independent variables in the equation). High multicollinearity causes a reduction in the efficiency of the estimates of the coefficients in the regression equation, making both the point estimates and the standard errors of the regression coefficients unreliable. Because no issue in this litigation hinges on monetizing the value of any particular technical feature of an iPod, nothing is gained by adding more characteristics that do not increase the explanatory power of the regression but reduce the precision of the estimates of the coefficients.

Fourth, Professors Murphy and Topel argue that my regression analysis suffers from non-independence of the observations that arise from clustering effects. [REDACTED]

[REDACTED]

[REDACTED] The solution to this alleged problem that Professors Murphy and Topel propose is to collapse the transactions data by using only one observation for each specific price that Apple charges for a given iPod model during a calendar quarter and then weighting that observation by the quantity of that iPod model that was sold in that quarter at that price. At every step of the way, this argument by defendant's experts is incorrect as matters of fact and econometric theory.

Defendant's experts are incorrect to claim that each transaction is not an independent observation because Apple sets all prices. The statistical concept of independence is *not* about whether different people set the price for different purchases, but about the distribution of the error term in the price equation. For example, all of the laws of physics are set by nature, but in an appropriately designed experiment separate observations of natural phenomena that are collected for the purpose of quantifying these laws are independent observations. Notwithstanding that Apple sets the price of each iPod, each Apple customer makes a separate, independent decision whether to buy that iPod, some other iPod, some other brand of portable digital media player, or no portable digital media player at all, and, if the decision is to buy a particular iPod, how many to purchase. Thus, each transaction record is analogous to a single experimental trial to measure a law of nature, and so is properly regarded as an independent event.

[REDACTED]

[REDACTED] Clustering problems arise because of the way that a sample of observations is drawn from a larger population. A cluster sample consists of a data-gathering technique that divides all observations into groups, selects a sample of these groups from which observations will be drawn, and then, for each sampled group, takes a sample of observations within the sampled groups. The issues that give rise to a cluster problem are: (1) observations from a sample of groups may not be representative of observations in all groups, and (2) membership in a group may be correlated with other factors that could influence the dependent variable in the regression but that are not included as independent variables in the regression.

Clustering does not apply to Apple's transactions data because these data are not a sample, let alone a clustered sample. Apple's transactions data include the entire population of all sales by Apple, not a sample of Apple's sales for some models of iPods. Moreover, even if the data were a sample of sales from a sample of iPod models, as the number of clusters increases (here, the number of iPod models and calendar quarters), the sampling error from clustering converges to zero. In Apple's transactions data the number of iPod models per calendar quarter is large enough to eliminate a concern about problems from clustering.

A standard procedure for reducing cluster effects is to include indicator variables

for clusters. This procedure does not work if the number of clusters is small (i.e., a handful), but does work if the number of clusters is large. The regression equations that I use include a large number of indicator variables for iPod classes and capacity, so even if the data were a cluster sample the clustering problem would not be important. Finally, even if the number of clusters is small and observations are from a cluster sample, the proposal to divide sales of iPod models into calendar quarters does not solve the problem. Dividing the observations in each cluster among calendar quarters does not make the sample more representative and does not correct for correlations between the identity of a cluster and excluded independent variables.

For these reasons the criticisms by Professors Murphy and Topel regarding the alleged lack of independence of price observations and the presence of cluster effects are without merit. The sole effect of their proposal is vastly to reduce the number of transactions observations that are used to estimate the regression equation, thereby reducing the explanatory power of the regression analysis by eliminating most of the true variance in price among transactions and, thereby, destroying the reliability and precision of the regression results.

Recalculated Damages

Apple produced new information after the submission of the *Noll Corrections Report* about the models of iPods that made use of iTunes 7.0 and its successors. I have re-estimated the damages model making the following changes in the specification and estimation procedures. First, the indicator variable for iTunes 7.0 takes the value one only for models of iPods that used this version of iTunes, and not for other iPods that

were sold after September 12, 2006, when iTunes 7.0 was launched. Second, because older versions of iTunes, beginning with iTunes 4.7, that used previous methods for blocking Harmony continued to be used on other iPod models, the “Harmony Blocked” indicator variable continues to take the value one for these models until the end of the data period. Third, to take into account the fact that RealNetworks introduced a second version of Harmony that worked around the disablement of the first version of Harmony by iTunes 4.7, I added a second indicator variable that takes the value of one for all transactions after the second version of Harmony was released. Fourth, I have adopted January 6, 2009, instead of March 31, 2009, as the date on which the “DRM-free” variable takes the value of one and for which damages end. Fifth, I have replaced the logarithm of time in the regression by the scalar measure of time. Sixth, I have estimated the equation using quantity-weighting, rather than frequency-weighting.

[REDACTED]

LIABILITY ISSUES

Professor Murphy argues that the analysis of liability in the *Noll Merits Report* is implausible because it does not deal with several issues that Professor Murphy believes are important. On all counts Professor Murphy's arguments are not based on economic analysis and are incorrect.

Superiority of Closed Systems

According to Professor Murphy, my analysis ignores “pro-competitive reasons” (*Murphy Report*, p. 4) for creating closed systems. I do not ignore the fact that, in principle, a closed system may perform better than a system in which the components are acquired from separate vendors. Regardless of whether an iPod actually performs downloads from iTunes better than downloads from the RealPlayer Music Store (RMS) or Amazon is irrelevant.² The relevant issue is not whether Apple is correct in its beliefs about the superiority of all-things Apple, but whether forcing consumers to buy either all or no complementary products from Apple is a reasonable restriction on competition.

In the absence of actions to disable the use of competing products, consumers can judge for themselves whether Apple's “walled garden” is superior, rather than delegate this evaluation to Apple. To prove that this restriction is reasonable requires showing

² The *Murphy Report* (pp. 19-31) contains a discussion of Apple's closed system, but does not contain any information that is relevant to the issue of whether a download from one of the competitors of iTunes is in any way inferior to a download from iTunes. Moreover, this discussion ignores two facts: before the iTunes Music Store was launched in April 2003, iPods loaded music from CDs, which are not in a protected format and can be loaded to a portable digital media player, and since January 2009 downloads have been sold without DRM protection from all Internet vendors, without doing any harm to iPods or iPod users. Thus, there is no evidence for the premise of Professor Murphy's argument that closed systems perform better than systems with components from different vendors.

that the performance of an iPod is degraded if it tries to play a download from a vendor other than iTunes and that consumers are harmed if they are allowed to make their own decisions about where to acquire downloads. Professor Murphy offers no economic evidence to support either of these arguments.

Extent of Use of Harmony

Professor Murphy asserts that proof of liability must involve showing that iPod owners used Harmony and purchased downloads from the RMS (*Murphy Report*, pp. 4, 33). This claim also is incorrect. The economic argument about the effects of changes in the market conditions for portable digital media players is that they affected the relative prices of iPods. If Apple lowered iPod prices due to Harmony and raised these prices after Harmony was blocked, the purpose would have been to minimize the extent to which consumers changed their pattern of consumption among both portable digital media players and sources of downloads of sound recordings.

Nothing in the economic theory of demand indicates, as Professor Murphy implies (*Murphy Report*, p. 6), that some threshold level of users of Harmony among iPod owners is necessary for Harmony to have had an effect on iPod prices. Instead, the effect of a technology that allows consumers to buy complementary products from different vendors is to make the price of these components more elastic, and the effect of conduct that eliminates this possibility is to make demand for components less elastic. If Apple managed to avoid most or even all of a switch in sales arising from a technology such as Harmony by lowering prices and improving its products, one could observe little or no actual use of the technology because it was discouraged by the price effect.

Double Marginalization

Third, the *Murphy Report* (p. 21) argues that the sale of complementary products by a single seller necessarily lowers the prices of components because the single seller can take into account the effect of the price of one component on the sale of another. This argument is based on the premise that each component is sold by a firm with monopoly power. Elsewhere Professor Murphy notes that RMS accounts for a few percent of download sales, which is inconsistent with the premise that RealNetworks possesses significant market power. Professor Murphy's argument is incorrect if the markets for complementary products are competitive. Moreover, if Professor Murphy's argument were correct, a firm that sold all of the complementary products would not need to make components incompatible with complementary products from other suppliers because it would obtain all sales without creating lock-in by charging lower prices.

Market Definition and Market Power

The *Murphy Report* (pp. 6, 59-63) makes several arguments challenging the analysis of market definition and market power in the *Noll Merits Report*.

According to Professor Murphy, a digital download of sound recordings "is a 'market' without meaning" because the "central question" is whether iPod users are locked in to iPods and RMS cannot possibly be important in determining whether iPod users are locked in because it has "a very small share of any music on an iPod" (*Murphy Report*, p. 6). Here Professor Murphy confuses the issue of defining a market with the issue of whether Apple's conduct reduced competition in that market. The low market

share of RMS, which entered after the iTunes Music Store (iTMS) was launched, is the expected consequence of lock-in by the dominant provider of portable digital media players at the time that RMS entered the market. The *Murphy Report* (p. 61) also states that the definition of the market in which iTS operates is “irrelevant” because “Plaintiffs have not alleged that Apple attempted to increase prices for digital downloads above the competitive level...” Whether Apple’s pricing of digital downloads is monopolistic or competitive is not a relevant issue in this case. Here Professor Murphy ignores that market power is the ability of a firm to cause prices to exceed the competitive level or to exclude competitors. The latter is the relevant issue in this case, and the definition of the relevant market in which iTS competes is relevant to determining whether Apple has excluded competitors.

Professor Murphy claims that all forms of obtaining music, including physical copies (CDs), on-demand Internet streaming, and illegal file sharing should be in the relevant market that includes iTS. Market definition is about identifying the close competitive substitutes for a reference product (here, iPods and digital downloads). Professor Murphy does not show that CDs, illegal file sharing, and on-demand streaming services are equally close substitutes for iTS as a competing source of permanent downloads. The *Noll Merits Report* (pp. 31-42) explains why these other sources of recordings are not as close substitutes for iTS as other Internet sites that sell permanent downloads of recordings. Briefly, the success of sites like iTS, RMS, Amazon and others demonstrates that many consumers do not want to obtain recordings in a way that infringes copyrights. Notwithstanding Professor Murphy’s dismissal of the point, on-demand streaming services for play on portable devices were not important until after the

end of the class period, so whether they were in the relevant market is irrelevant to the issue of whether Apple enjoyed market power in digital downloads. Finally, CDs are not the closest substitutes for digital downloads because they are bundles of many recordings in a pre-programmed format.

The *Murphy Report* (pp. 61-62) also disputes my analysis of the market power that Apple enjoys in the market for portable digital media players. According to Professor Murphy, lock-in played no role in the success of iPods, based on the observation that “Apple achieved great success and was able to charge a price premium even *before* it was established as the market leader.” Here Professor Murphy seems to agree that Apple enjoyed market power in portable digital media players, and instead is disagreeing with the conclusion that Apple’s market power increased with the launch of iTunes and its resulting lock-in effect. The “great success” with iPods before iTunes involved obtaining a far lower share of a far smaller market for portable digital media players than existed after iTunes and other digital download sites were launched. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

In summary, Professor Murphy’s opinions on market definition are not based on an application of the methods that economists use to define a relevant market, and his analysis of market power does not deal systematically with the relevant facts that an economist would use to determine whether a seller has market power and, if so, how its

market power has changed over time.

Simultaneous Improvements

The *Murphy Report* (p. 6) argues that the iTunes 7.0 variable measures more than just the effect of disabling Harmony, but also other technical features that occurred simultaneously. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

ECONOMETRIC ISSUES

Professors Murphy and Topel assert that the econometric model that I use to demonstrate anticompetitive injury and to calculate damages on a class-wide basis is unreliable for three reasons: (1) the use of frequency weights on each transaction record; (2) the details of the specification of the regression equation; and (3) the failure to take into account an alleged clustering of the data that causes transaction observations not to satisfy the assumption that observations in the data set are independent. Professors Murphy and Topel further claim that if the model is adjusted to take their criticisms into account, the estimated effect of iTunes 7.0 on iPod prices is zero, implying that

consumers were not damaged by disabling Harmony.

Weighting

The *Murphy Report* (p. 47) and the *Topel Report* (pp. 25-27) criticize the use of frequency weighting of observations in the regression model on the grounds that it causes the precision of the regression coefficients to be over-estimated. As Professors Murphy and Topel state, the price of a specific iPod (model/generation/family) in each transaction is calculated as the ratio of the total charge for that specific iPod divided by the number of units of that iPod that were purchased. Thus, the unit of observation in the regression analysis is a transaction that includes this calculated price and values for the other independent variables, including the indicator variables for class and capacity, variables representing the sales quantity in the transaction, and variables indicating technical features of iPods. The sales quantity was included as an independent variable to take into account the possibility of volume discounts.

[REDACTED]

The core of the weighting issue is as follows. The procedure for estimating a

regression equation calculates the values of the coefficients on the independent variables to minimize the sum of the squares of the prediction errors from the estimated equation. That is, if the true price in a transaction is P and the estimated price from the regression equation is P^* , the method for estimating the regression calculates coefficients that minimize the sum of $(P^* - P)^2$ over all transaction observations.

The most commonly used procedure for estimating an econometric model is an unweighted regression, which means that each observation is given equal weight in calculating the coefficients of the variables in the regression equation. Thus, a transaction in which 20,000 units of a specific iPod are sold is given the same weight as a transaction in which one unit of the same iPod is sold. If P^H is the price of the transaction involving 20,000 units and P^L is the price of the transaction involving one unit, a regression in which there were N transactions of one unit and one transaction for 20,000 units would minimize $(P^{H*} - P^H) + N(P^{L*} - P^L)$. For values of N that are greater than one, an unweighted regression produces a more precise estimate of P^{L*} than of P^{H*} .

The problem with using this procedure is that it yields a biased estimate of total damages because it does not take into account the fact that far more damages are at stake in obtaining an accurate estimate of damages for the transaction that involves 20,000 units than in accurately estimating damages for the one-unit transactions. In the preceding example, if there are 100 transactions for one unit, an error of ten cents in the estimate of P^L produces an error of \$10 in total damages, but the same error in the estimate of P^H causes an error in damages of \$2,000.

The standard solution to this problem is to weight each observation by the amount transacted. That is, in the preceding example, instead of minimizing the unweighted sum

$(P^{H*} - P^H) + 100(P^{L*} - P^L)$, the procedure minimizes $(20,000)(P^{H*} - P^H) + 100(P^{L*} - P^L)$.³

Notice that an unweighted regression assigns most of the weight to the small transactions, while a weighted regression assigns most of the weight to large transactions.

The *Murphy Report* and the *Topel Report* do not criticize my decision to estimate a weighted regression. Instead, their criticism is about the use of frequency weighting rather than quantity weighting. Frequency weighting causes the “degrees of freedom”⁴ in a regression to be overstated, which in turn causes an under-estimate of the standard errors of the regression coefficients.

I agree that, as a general proposition, quantity weights are preferred to frequency weights. But the choice between these weighting methods is not important in this circumstance for two reasons. First, the choice between frequency weights and quantity weights has no effect on the estimated coefficients of the independent variables and, as a result, the amount of damages. The *only* statistics that can be affected by the choice of weights are the standard errors of the coefficients and the measure of fit of the equation, which is adjusted R^2 . Second, when the number of observations is extremely large (here, in the millions), the effect of the choice of a weighting method on the outcome of tests of statistical significance of the regression coefficients and of adjusted R^2 is small. Once the degrees of freedom in a regression are in the millions, a further increase is unlikely to

³ Typically each weight is divided by a constant, such as the total quantity sold in all transactions. While this procedure makes the coefficients in the regression easier to interpret, it does not affect the fit of the equation, the statistical significance of the coefficients, or the amount of damages.

⁴ Usually the statistic “degrees of freedom” equals the number of observations minus the number of independent variables in the equation. In both data sets (direct and reseller) the number of observations is in the millions and the number of independent variables is less than 75, so the “degrees of freedom” statistic is in the millions. But if observations in the data are not statistically independent, the degrees of freedom statistic is adjusted downwards to reflect the extent of correlation among the errors in the observations.

have much of an effect on the outcome of tests of statistical significance for the regression coefficients or the equation as a whole.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] The effect of the weighting method also is greater if the data include “outlier” observations that are likely to be incorrect and, therefore, to create more unexplained variation in prices.

To illustrate that the choice of the weighting method has a minimal effect on the regression results, I estimated two identical versions of the original logarithmic regression equation in the *Noll Merits Report*, one with frequency weights and the other with quantity weights, using reseller data that includes outlier observations. These specifications do not make any of the changes in the regression equations that are discussed elsewhere in this declaration and that I have adopted in the new damages model and so directly address the claim by defendant’s experts that the use of frequency weights dramatically affected the results of my regression analysis.

The effect of the choice of a weighting procedure in the reseller regression is reported in Exhibit 1. As expected from statistical theory, the regression coefficients are identically the same in the frequency weighted and quantity-weighted equations, as is adjusted R^2 . The standard errors of the regression coefficients are larger in the quantity-weighted regression, but these differences are generally small compared to the values of the coefficients. The coefficients on the variables that are relevant for establishing

liability and calculating damages⁵ all remain highly significant.⁶ Exhibit 2 shows the results of switching from frequency weights to quantity weights for the direct sales regression. As expected, the differences in these results are limited to small differences in the standard errors of the coefficients, with all other results unchanged, including the coefficient on the iTunes 7.0 variable that is used to calculate the amount of damages.

These results show that, despite the advantages of quantity weights compared to frequency weights, the choice of a weighting method does not affect any conclusion in my previous reports. Nevertheless, in the new damages regressions reported elsewhere, I use quantity weighting rather than frequency weighting.

Specification Issues

Economists use the term “specification” to refer to the choice of a functional form of a regression equation and the choice of the independent variables that are included in the equation. Professors Murphy and Topel make five criticisms of the specification of the regression equations that are estimated in the *Noll Merits Report*.

The first criticism is that time should be included in a logarithmic equation as a linear variable, rather than a logarithmic variable (*Murphy Report*, pp. 52-53, and *Topel Report*, pp. 43-46). The second criticism (*Murphy Report*, pp. 51-52, and *Topel Report*, pp. 37-43) is that the indicator variable for the iTunes 4.7 and subsequent versions of iTunes that blocked the use of Harmony but that the Court has found to be legal should

⁵ These are the indicator variables for iTS Launched, Harmony, Harmony Blocked (iTunes 4.7), iTunes 7.0, Competitors DRM-free, and iTS DRM-free.

⁶ Two independent variables, the smaller quantity indicator and the indicator for 6GB of memory, are statistically significant in the frequency-weighted regression and statistically insignificant in the quantity weighted regression, but no conclusion in my prior reports hinges on the significance of these variables.

remain “on” to the end of the data period, rather than be replaced by iTunes 7.0 when the latter is released. The third criticism (*Topel Report*, pp. 20-21) is that the regression equation should include separate indicator variables for the two versions of Harmony that were released by RealNetworks. The fourth criticism (*Topel Report*, pp. 53-54) is that my original specification used the wrong date for the start of the availability of DRM-free music on iTunes. The final criticism is that the regression equation does not include measures of all possible technical characteristics of an iPod and other variables that might affect its price (*Murphy Report*, pp. 53-56, and *Topel Report*, pp. 47-49).

This section explains the issues that lie behind these criticisms. In three cases (the specification of time, the beginning date for DRM-free music, and the two versions of Harmony), I use the procedures that Professors Murphy and Topel recommend and find that they do not cause the coefficient on the iTunes 7.0 variable to become statistically insignificant and the amount of damages to become zero. In the other cases, I conclude that the criticisms by Professors Murphy and Topel are not valid.

Time

According to the *Murphy Report* (p. 53) and the *Topel Report* (p. 46), time in a logarithmic model should enter as a scalar, not the logarithm of time. In the revised damages regressions reported elsewhere, I use time, rather than the logarithm of time, in the logarithmic price regression.

iTunes 4.7 and Harmony

The damages equations that were estimated in the *Noll Merits Report* included a variable, “Harmony,” to indicate the availability of the Harmony software to enable iPod users to download music from Internet retailers that sold music in RealNetworks’ DRM format. These equations included two variables to measure versions of the iTunes digital media player software that disabled Harmony. The first, labeled “Harmony Blocked,” took the value of one after iTunes 4.7 was introduced and was switched to zero when iTunes 7.0 was introduced. The second, labeled “iTunes 7.0,” took the value of one from the time that iTunes 7.0 was introduced until the end of the data period. The *Murphy Report* (pp. 51-52) and the *Topel Report* (pp. 37-43) argue that this specification is incorrect and should be re-specified in two ways.

First, Professors Murphy and Topel propose that the equation should include two indicators for Harmony – one for the initial version, and another for a later version that to some degree got around the software in iTunes 4.7 that blocked the use of the first version of Harmony. I accept this proposal and have separated the Harmony indicator into “Harmony1” that takes the value of one after July 2004 and “Harmony2” that takes the value of one after April 2005.

The second proposal by defendant’s experts is that “Harmony Blocked” should be set equal to one until the end of the data period, thereby causing the iTunes 7.0 variable to measure the incremental harm arising from the replacement of earlier versions of iTunes that the Court had ruled to be legal. The context of this criticism is that in the regressions in the *Noll Merits Report*, Harmony was assumed to have been disabled on all models of iPods that were sold after September 12, 2006. The relevance of this criticism

has been affected by the fact that after the *Noll Corrections Report* was submitted, Apple provided new information about [REDACTED] [REDACTED] in iTunes 7.0 and its successors were enabled. [REDACTED] [REDACTED] continued to use the methods for blocking Harmony that were included in iTunes 4.7 and that had been worked around in the second version of Harmony. In the revised regressions the “Harmony Blocked” indicator remains set equal to one until the end of the data period for the models that were not affected by iTunes 7.0 and is set equal to zero for the iPod models for which the [REDACTED] were enabled.

I expect that Professors Murphy and Topel continue to think that “Harmony Blocked” should be set to one for iPod models on which the [REDACTED] were enabled, thereby blocking Harmony. I believe that this recommendation is unwarranted. For these models of iPods, Apple replaced technology that was ruled by the Court to be legal with new technology that plaintiffs allege was not legal. The proper way to measure the impact of enabling the [REDACTED] and using iTunes 7.0 is not to assume that these models contained the old blocking technology from iTunes 4.7, which is the implicit assumption in the proposal by Professors Murphy and Topel.

The Impact of iTunes 7.0

The *Murphy Report* and the *Topel Report* (p. 55) claim that the specification of the iTunes 7.0 variable is inappropriate for measuring the anticompetitive effect of blocking Harmony on the prices of iPods. Both argue that the lock-in effect arising from preventing iPod owners from downloading recordings from websites that used the RealNetworks encryption format would have become quantitatively more significant as

customers bought more recordings from Apple, and conclude from this argument that the effect of iTunes 7.0 on iPod prices should have been gradually to increase them. The problem with this argument is that it focuses on only one way in which the creation of a mandatory closed system of products reduces competition and raises prices.

This argument ignores the fact that iTunes 7.0 immediately locked out a customer who has been using a portable digital media player that used the RealNetworks DRM format and who had purchased downloads from RMS. The immediate effect of iTunes 7.0 was to reduce the expected benefit to Apple in increased iPod sales from engaging in price competition with these other portable digital media players, thereby causing the demand for iPods to be less price elastic. The effect of lock-out is immediate, and the principal anticompetitive effect of blocking Harmony on iPod prices arises from the general reduction in competition among iPods and other portable digital media players arising from the lock-out effect.⁷

The argument by defendant's experts also is incorrect for another reason. Whereas new iPod owners in late 2006 became more locked in to iPods over time, the effect of this lock-in would not have affected the demand for subsequent iPods for a long period because these purchasers would not soon make repurchase decisions. Thus, for most of the damages period, the lock-in effect on new iPod purchasers would not be an important factor affecting iPod prices.

⁷ The *Murphy Report* (p. 37) argues that lock-in makes an iPod less valuable and so, as a matter of economic theory, reduce its prices. This statement is not true and reveals a lack of understanding of the economic of lock-in effects. Lock-in makes otherwise identical products less perfect substitutes, and thereby reduces the intensity of price competition among these products.

DRM-Free Music

The *Topel Report* (pp. 53-54) criticizes my use of the date of March 31, 2009, as the starting point for the availability of DRM-free music on the iTunes Store (iTTS). The basis for this criticism is that Apple announced in January 2009 that as of that date 80 percent of the recordings on iTTS were available in a DRM-free format. Professor Topel reports that he reset the start date of the DRM-free music variable “three months earlier, as of January 6, 2009” (*Topel Report*, p. 54) and that this change reduced the effect of iTunes 7.0.

The relevant variable for measuring the effect of the availability of DRM-free downloads on iTTS is not the fraction of titles that were available in a DRM-free format, but the popularity of those titles. The impact of the catalog of DRM-free music could be approximated by the relative sales of DRM-free music versus other music on, say, a weekly basis. But these data were not produced by Apple in this litigation and so cannot be put into the regression equation. Without such data, any specification of the effect of DRM is going to be partially incorrect. For example, the implicit assumption that the full effect of DRM-free music occurred immediately on January 6, 2009, is clearly incorrect. The importance of the error in specifying the DRM-free start date as January 6 depends on the popularity of the titles that were not available in a DRM-free format on that date.

In the revised damages regressions reported elsewhere, I have used January 6, 2009, rather than March 31, 2009, as the beginning of the DRM-free period on iTTS. The effect of this change is to cause true damages to be underestimated because not all recordings were available in a DRM-free format on that date. The likely effect of this change is a small reduction in the amount of damages. This effect is likely to be small

because the duration of the period being reclassified is short.

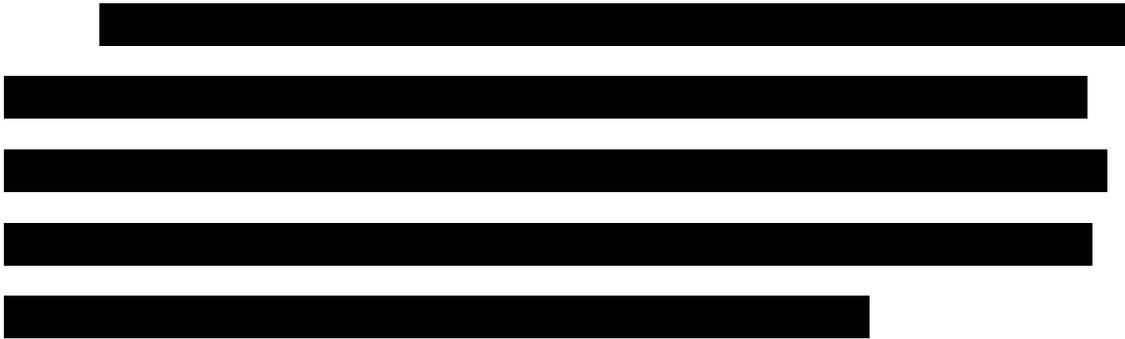
Excluded Variables

Professors Murphy and Topel argue that the damages equations that I estimated in my prior reports have low quality. One reason they give is that some coefficients appear to have the “wrong” sign, and the other is that some variables are excluded. For example, the *Topel Report* (p. 47) observes that photo capability and photo and video capability both have negative regression coefficients, which Professor Topel interprets as causing the price of an iPod with these features to be lower than if these features had been left out. According to the *Topel Report* (p. 47), “there can be little doubt that these features are valuable to users.” Professor Topel then adds several new variables that measure technical characteristics of iPods to the regressions (*Topel Report*, pp. 48-49, Exhibits 13A and 13B). A related criticism (*Murphy Report*, p. 55) is that the equations fail to take into account the profit margin of products, which Apple’s committee for setting prices states is an important element of decisions about prices.

These criticisms are incorrect for the same reason. The average incremental cost of an iPod model is included in the regression.

Professor Murphy’s proposal to add profit margin to the regression equation is entirely inappropriate. The cost of an iPod model is the basis for setting its profit margin. The cost variable that already is included in the regression incorporates the consideration of margins by Apple in setting prices. Adding margin as another independent variable, far from improving matters, would constitute a fatal econometric error because it would cause the dependent variable, price, to appear on both sides of the equation. If P is price,

C is incremental cost, and A, b and c are coefficients to be estimated in the regression, then the regression equation is $P = A + b(P - C) + cC = A + bP + (c-b)C$. In this meaningless regression, the estimate for b would be one, while A and (c-b) would be zero, and the equation would prove precisely nothing.



Professors Murphy and Topel's argument that many technical characteristics of an iPod plausibly affect its value and so should be included in the hedonic price equation also is not useful. The problem with this claim is that it loses sight of the reason for estimating the hedonic price equation. The goal of the hedonic price equation is to explain as much of the variation in price as possible, using measures of product features. One important variable that captures a bundle of iPod characteristics is the iPod class. Thus, if variables for all of the specific technical characteristics that distinguish an iPod touch from an iPod nano were added to the equation, these variables would not add explanatory power because they already are captured in the class indicator variables.

Professor Topel finds that adding additional technical characteristics has an extremely small effect on the explanatory power of the regressions that I reported,⁸ and

⁸ When Professor Topel adds more variables that measure technical characteristics to the regression equations, R^2 increases by .0063 in the reseller equation and by .0053 in the direct sales regression.

claims that this justifies including them.⁹ But adding more variables that have a minimal effect on the explanatory power of a regression is worse than simply being unnecessary. If some variables that are sources of value in an iPod add little explanatory power when they are included in the regression equation, the reason is that they already are highly correlated – if not perfectly correlated – with variables that already are in the equation. For example, the indicator variable for an iPod nano is perfectly correlated with any indicator variable for a feature that is found only in an iPod nano. The term that econometricians use for including highly correlated variables in the same regression is multicollinearity, and perfect multicollinearity of this form makes estimating a regression equation impossible.

The problem that multicollinearity creates is to reduce the precision of the estimated coefficients in the regression, making them less reliable as estimates of the true effect of an independent variable on the dependent variable. Thus, the effect of piling on more iPod characteristics that add no explanatory power to the hedonic regression is to cause all of the estimated coefficients, including the coefficient on iTunes 7.0, to become less reliably estimated.

If the goal of a regression were to estimate the contribution of a particular technical characteristic to the price of an iPod, then adding highly correlated variables might make sense if the loss of precision in estimating the coefficients were not so great that many, if not all, coefficients became statistically insignificantly different from zero. But the goal here is not to determine the implicit value of the attributes of an iPod, but to produce a formula for calculating damages. The latter does not depend on the values of

⁹ *Deposition of Robert Topel*, pp. 149-50.

the coefficients on technical characteristics, but the reliability and precision of the coefficient on the iTunes 7.0 indicator.

Independence and “Cluster Effects”

Both the *Murphy Report* (pp. 45-50) and the *Topel Report* (pp. 33-37) argue that the methods that I used to analyze Apple’s transactions records are based on an erroneous assumption that the transactions observations are independent when, in fact, these observations occur in “clusters” of correlated observations. According to Professor Murphy (*Murphy Report*, p. 46), I “made a fundamental error” in constructing my data set and interpreting the regression results because I assumed that “literally millions of identical price ‘observations’ are statistically independent.” The *Murphy Report* (p. 48) also states that the “prices paid by purchasers (either individual consumers or resellers)... were all set by Apple...” and “the vast majority of the prices for the same model in the same time period were identical.” Professor Murphy then asserts that these facts cause the observations to violate the independence assumption. Professors Murphy and Topel claim (*Murphy Report*, p. 49, and *Topel Report*, pp. 35-36) that the residual errors in the prices of each iPod model in each calendar quarter are correlated, by which they mean that the average residual error in each quarter is not zero. From this result, Professors Murphy and Topel conclude (*Murphy Report*, pp. 49-50, and *Topel Report*, pp. 36-37) that the data are “clustered” according to the family of the iPod and that the proper method for analyzing these data is to collapse all transactions at a given price for each class/generation/family of iPod in a calendar quarter into a single observation.

At every step of the way this series of arguments is incorrect.

“Millions of Identical Prices”

Apple and its experts repeatedly have claimed that all Apple customers pay the same price. This claim is untrue and is easy to disprove using Apple’s transactions data. Appendix B contains histograms of the price and quantity data for every iPod family for every calendar quarter during the entire data period. The reseller and direct purchaser data are shown separately. Each figure shows the distribution of the prices charged and the number of transactions at that price for each calendar quarter. The reseller transactions data show substantial within-quarter variation in prices. The direct sales data show that most transactions are at list price, but many are not. Thus, a major premise of the arguments put forth by Professors Murphy and Topel – that all or virtually all prices of a given iPod model are identical – is wildly incorrect. Moreover, these data understate the true variation in prices because Apple has not provided the information that is necessary to match all discounts to a specific transaction.

The Independence of Residual Errors

The *Murphy Report* and the *Topel Report* argue that the transactions observations that were used to estimate the regression equations contain “clusters” of observations, defined as sales of a single iPod class/generation/family during a specific calendar quarter, in which the residual errors of the regression equation are correlated within each cluster, and that as a result the regressions that I report are unreliable because they do not include a correction for this cluster effect. These claims are incorrect, partly because the statistical analysis that Professors Murphy and Topel use to demonstrate within-cluster

correlation is incorrect, and partly because applying the concept of cluster analysis to the Apple transactions data is inappropriate as a matter of econometric theory.

In the empirical analysis that Professors Murphy and Topel present to prove that errors are correlated within a cluster, Professors Murphy and Topel calculate the residual error of the estimated price for each sale of an iPod within a cluster, divide the sample of residual errors into two equal size groups, and show that the mean error in the two groups is correlated. This analysis does not show that residual errors are correlated. Instead, this analysis shows that the two samples generate similar estimates of the mean residual error, which is to be expected if the samples are drawn randomly. Professors Murphy and Topel do not test whether the mean residual errors from this procedure are statistically significantly different from zero, which would have to be the case if the errors within a cluster are correlated. Thus, the analysis of residual errors by Professors Murphy and Topel does not actually test whether residual errors are correlated within a cluster.

Another problem with the procedure that Professor Murphy and Topel adopt is that it is based on the erroneous assumption that the proper unit of analysis is the sale of one iPod, not a transaction that may involve the sale of many iPods. The procedure that is used by Professors Murphy and Topel to test for correlation of residual errors calculates the residual error for each unit sold, which means that in the Best Buy examples cited above, Professors Topel and Murphy will count the same residual error in each of these transactions about 20,000 times. Of course, all of these 20,000 residual errors will be the same, so if 10,000 are assigned to each of the two groups of residual errors for each cluster, the mean values of the residual errors for each group will be correlated simply because the same observation has been counted so many times in both

groups within the cluster.

My regression analysis is based on the assumption that the proper unit of analysis is a transaction and that the error in the price equation is independently distributed across transactions, not across each unit sold in a multi-unit transaction. Although I weight a price observation in a transaction by the number of units of a given iPod that are sold in order to better fit the prices for multi-unit transactions, the appropriate residual error for a transaction is a single observation on the difference between estimated and actual price for the transaction, not for each unit in the transaction. Thus, the appropriate procedure to test for within-cluster correlation of errors is to examine the residual errors of transactions, not the residual errors of the price of each unit sold.

As a practical matter, a particular model of iPod is represented by class and capacity variables in the regression. One consequence of this procedure is that the mean residual error for a specific class or capacity of iPod over the entire period in which it was sold must be zero. This does not mean that the mean residual error is necessarily zero in any specific calendar quarter – indeed, the probability that every quarter will have exactly the same mean residual error is zero, even without any specification problem in the equation. But Professors Murphy and Topel do not even attempt to determine whether mean residual errors for transaction prices actually vary from quarter to quarter for a given model of iPod and, if so, whether the differences are statistically significant or quantitatively important.

The Relation between Independent Observations and Clustering

Professors Murphy and Topel discuss the independence of observations as if the concept of independence applies to whether the price differs among observations. In fact independence refers to the error term in the regression equation. Professors Murphy and Topel are incorrect to state that two transactions involving the same product and the same seller at exactly the same price necessarily are not independent. Even for sales at the same posted price, the observations are independent because each transaction involves a different buyer making an independent decision about whether to make a purchase and, if so, how many products to buy. The price equations that are used to calculate damages include variables that can affect supply (Apple) and demand (customer) decisions. Thus, counting each transaction as a separate, independent observation is appropriate.¹⁰

Even using the same observation more than once does not cause the independence assumption to be violated and can be statistically useful. A technique for dealing with small data sets is “bootstrapping,” which is used in correcting some clustering problems.¹¹ The simple bootstrap method involves taking a random sample with replacement from the original data (i.e., randomly drawing an observation, recording it,

¹⁰ Economists frequently use data sets with many transactions at the same price to study supply and demand conditions in a market. For example, a study of grocery transactions used all recorded retail sales to calculate the extent to which prices were correlated among stores and the extent to which retail price changes were in response to wholesale price changes. On a given day, the price of any specific grocery item was likely to be identical in all sales, but differences in the identity of the purchaser and the quantity purchased made each transaction a valid observation. See Emi Nakamura, “Pass-through in Retail and Wholesale,” *American Economic Review Papers and Proceedings*, Vol. 98, No. 2 (May 2008), pp. 430-37.

¹¹ A. Colin Cameron and Douglas L. Miller, “A Practitioner’s Guide to Cluster-Robust Inferences,” *Journal of Human Resources* (forthcoming), pp. 14-15.

and returning the observation to the data set before the next random draw).¹² Sampling with replacement implies that the same observation may be drawn more than once, causing duplication of observations. A regression is estimated from this sample. This procedure is repeated many times to produce many estimates of the regression coefficients. The distribution of the regression coefficients is then used to construct an estimate of the true coefficient.

If a valid statistical procedure that does not violate the independence assumption can involve using the same observation more than once, the fact that the prices in two distinct transactions are the same or were set by the same person cannot, by itself, violate the independence assumption. Consider the problem of measuring the true acceleration of a falling body due to gravity. Just as Apple determines every price and all of the technical features of every iPod, so does nature set the true values for V , g and t in the equation $V = gt$, where V is velocity, t is time, and g is the acceleration due to gravity of a freely falling body. One can perform an experiment in which many observations are made of V and t , and from these measurements one can estimate g . The fact that every measurement is determined by exactly the same law of physics does not cause these observations to violate the independence assumption.

In estimating the equation for V , problems can arise with the data. First, V and t may not be measured accurately. Second, other factors may influence the speed of the

¹² For a comprehensive discussion of bootstrapping, including methods that do not use sampling with replacement, see Joel L. Horowitz, "The Bootstrap," in James Heckman and Edward Leamer, *Handbook of Econometrics*, Vol. 5, North Holland (2001), pp. 3159-228. For a simpler discussion focused on regression analysis, see David A. Freedman and Stephen C. Peters, "Bootstrapping an Econometric Model: Some Empirical Results," *Journal of Business and Economic Statistics* Col. 2, No. 2 (April 1984), pp. 150-58.

falling object, such as imperfections in the release of the object and friction due to air resistance, in which case the simple equation for V has a specification error in that variables that influence V are excluded. Third, some sources of error may be random variables with an expected value at or near zero, in which case a larger number of measurements will produce a smaller error in the estimate of g . The experiment in a physics lab to try to measure g does not include observations of every object that has ever fallen anywhere on earth, but is a sample of all such events, and the larger the fraction of all possible events that is included in the sample, the more accurate will be the estimate of g . The problem arising from this fact is called sampling error.

A standard linear regression to estimate g from a sample of observations on V and t assumes that these errors are *independent* – that is, that the magnitude of the error in one observation does not reveal any information about the magnitude of the error in another observation. This assumption would not be true, for example, if the measurement errors were due to a design flaw in the clock that measured t so that all such measures were, say, 10 percent too high for all values of t that were observed. The presence of this problem has nothing to do with whether the true underlying relationship is identically the same for all observations – that is, whether nature sets physics formulas or Apple sets pricing formulas – but whether the errors in trying to estimate either are independent.

Within this framework, clustering refers to one reason that the independence assumption might not be true. Specifically, clustering refers to how observations are collected. In the physics experiment, the observations on V and t are taken in the same lab using the same equipment. If the acceleration due to gravity depends on location and the accuracy of measurements depends on the equipment that is used, some of the errors

in the equation for V will be correlated among all observations from the same laboratory using the same equipment. Consequently, the observations of V and t will not be representative of objects that have fallen in other locations and could have been measured by other types of equipment. Here the simple equation has a specification error in that the variables for the measurement equipment and the location of the lab are not included in the equation.

Clustering arises when a sample of observations suffers from the type of problem that is represented by a dependence of the observations on the location of the experiment and the equipment that is used. If the sample consists of observations taken randomly at every location on earth using equipment that is drawn randomly from all possible types of measuring devices, the independence assumption is satisfied; however, if observations are taken at one laboratory using one clock and one radar gun for measuring velocity, the errors in estimating the equation for estimating g are likely to depend on location and equipment, and so are not independent.

The significance of the sampling aspect of cluster effects is that cluster analysis is irrelevant if the data set is either representative of the entire population of observations or is not a sample at all, but in fact is the entire population. In fact, Apple's transactions data are a population, not a sample, of all transactions of iPods. Moreover, Apple's customers were not randomly assigned to a model of iPod, but freely chose which iPods they purchased.

For still another reason cluster analysis is irrelevant to the issue of undertaking a regression analysis of Apple's transaction data. In fact, cluster analysis pertains to a form of regression equation that differs from the regression equations that I estimated. To

understand why cluster analysis is irrelevant for this reason it is useful to examine the type of problem that cluster analysis is designed to solve.

The problem of clustering has been extensively analyzed in the study of the effects of curriculum changes on the educational outcomes of children. The problem is to use regression analysis to determine the effect on the outcome (e.g., test score), Y_{ig} , for person i in group g of a treatment variable (e.g., a new curriculum) X_g , that takes the value one if group g , to which person i belongs, received the treatment and zero otherwise.¹³ The regression equation is then:

$$(1) \quad Y_{ig} = A + bX_g + e_{ig},$$

in which A is a constant, b is the coefficient on the treatment, and e_{ig} is the error in the estimate of Y for person i in group g . The standard assumption about the error term is that it is independent and identically distributed with a mean of zero and a finite variance, which means that the value of e_{ig} does not depend on any of the other variables in the equation and that the variance of the error term is the same for each observation.

The more general regression framework assumes that the regression contains two types of independent variables.¹⁴ The first type, X_g , applies commonly to all members of group g . For example, if a treatment is applied to some groups but not others, X_g is one for groups with the treatment and zero otherwise. The second type, Z_{ig} , is any variable

¹³ The standard notation in cluster analysis is based on the convention of separately numbering the members of each group, so that Y_{14} refers to the first person in the fourth group and Y_{16} refers to the first person in the sixth group.

¹⁴ The analysis presented here is based on discussions of cluster effects in Jeffrey M. Wooldridge, *Econometric Analysis of Cross Section Data*, MIT Press (2002), especially Chapter 11, Section 11.5, pp. 328-332; Jeffrey M. Wooldridge, "Cluster Sample Analysis in Applied Econometrics" *American Economic Review* Vol. 93, No. 2 (May 2003), pp. 133-38; Joshua D. Angrist and Jörn-Steffen Pischke, *Mostly Harmless Econometric: An Empiricists Companion*, Chapter 8, pp. 293-325, Princeton University Press, 2009; and Cameron and Miller, *op. cit.*

that takes different values for individuals within a group. A variable of this type may or may not apply to more than a single group. The outcome variable is Y_{ig} for person i in group g , and the estimated regression equation is then:

$$(2) \quad Y_{ig} = A + bX_g + cZ_{ig} + e_{ig},$$

in which c is the regression coefficient on Z_{ig} . Of course, there can be several different treatment variables (X_g) and individual variables (Z_{ig}), in which case all the variables are interpreted as vectors, but I ignore this complexity here.

The econometric problems that can arise in the more general specification involving clusters are as follows. First, the outcome for a member of a group may be affected by factors other than the treatment variable that are common to all group members. Second, the outcome of an individual may be influenced by an individual-level variable that is not included in the regression but that is correlated with the group to which an individual belongs. Third, the assumption of independent and identical distributions for the error terms may be violated in that the mean and variance of the errors differ among groups.

The first two problems are examples of an omitted variable, which is a form of specification error. The first problem arises because the treatment and other common causal factors are all rolled into the same variable, the group indicator X_g . For example, if a group is students in a particular class at a particular school, the quality of the teacher can affect outcomes as well as the treatment effect. The second problem arises because not all individual-level variables are represented in Z_{ig} . For example, if a group is students in a school, the education of the parents may differ between schools that are given the new curriculum and schools that continue to use the old curriculum. In both

cases, the estimated coefficient on the treatment effect in (2) will confound the effect of the treatment with the effects of other variables that are correlated with it.

The standard solution for omitted variables problems is not to omit variables. One straight-forward way to add variables that take into account factors that are common within a group is to add indicator (fixed effect) variables for each specific group and additional variables that may be correlated with the identity of the group. “If the model includes cluster-specific fixed effects, and we believe that within-cluster correlation of errors is solely driven by a common shock process, then we may not be worried about clustering. The fixed effects will absorb away the common shock, and the remaining errors will have zero within-cluster correlation. More generally, control variables may absorb systematic within-cluster correlation.”¹⁵

To illustrate the omitted variable problem in cluster samples, regressions using equation (1) have generated results implying that smaller class sizes cause improvements in test scores. Subsequent analysis shows that this simple model over-estimates the magnitude and statistical significance of the effect of class size because smaller class sizes tend to be found in schools in which students have wealthier, more educated parents and better teachers. If these other factors are included in the regression, the effect of class size falls substantially (sometimes to zero). Moreover, the new estimate of the class-size effect is much smaller than the lower bound of the 95 percent confidence interval on the coefficient for class size in the simple regression. This result shows that the simple regression under-estimated the standard error of the regression coefficient as well as over-estimated the value of the coefficient.

¹⁵ Cameron and Miller, *op. cit.*, p. 21.

The third potential problem in equation (2) is that the error terms may not be independent and identically distributed. Instead they may exhibit autocorrelation (e.g., if observations are arranged by group, errors within a group will tend not to average zero) and/or heteroskedasticity (e.g., the variance of the error term may differ among groups). In an analysis in which individual observations are assigned to groups, the variance of the standard errors can differ among groups if the number of observations in each group differs or if excluded variables apply to some groups but not others.

The importance of problems related to the error term depends on the nature of the data. One standard solution to these problems is to add more data by including more clusters in the sample. As the number of groups (clusters) grows larger, the importance of within-cluster error problems diminishes. The other standard solution is to test for and correct autocorrelation and heteroskedasticity.

The next issue is how clustering problems relate to estimating the price effect of a change in competitive conditions in the market for iPods and the equations that I have estimated to measure these effects. Professors Murphy and Topel define a cluster as a group of iPod transactions for a specific class/generation/family of iPod in a specific quarter during the data period. These clusters bear no relationship to the clustering problem in econometrics. The entering assumption of clustering models is that the individuals that are represented in the data can be divided into groups that are affected by common factors. “A cluster sample is typically a cross-section on individuals... where each individual is part of a cluster.”¹⁶ The individuals in the Apple transaction data include resellers – distributors and retailers who sell Apple iPods. Most of these Apple

¹⁶ Wooldridge, 2002, *op. cit.*, p. 229.

customers appear in many (perhaps all) clusters. Likewise, even some direct purchasers buy more than one model of iPod. In each case, the purchaser *decides* which iPods to buy, rather than being assigned to buy a specific model by Apple. Thus, the transactions data are *not* analogous to test scores of students from different classes that are assigned different teaching materials. Likewise, the seller always is Apple – the clusters do not represent different individual sellers that may not be representative of all sellers.

Professors Murphy and Topel cluster transaction observations by time periods. The necessary condition for a correction for clustering to be useful is that strictly “within-cluster correlation” is “substantial, which means the usual OLS standard errors can be very misleading.”¹⁷ There is no plausible reason to believe that a distinct group-specific effect influences transaction prices for a given class/generation/family of iPod differently in two adjacent quarters. Neither the seller nor the product changes between quarters, nor does the formula that Apple uses to set list prices and to give discounts to resellers. For most resellers the identity of buyers (such as ██████████) also does not change from quarter to quarter. There is no basis for assuming that two clusters that are adjacent in time but otherwise represent sales of the same iPod are substantially affected by different common group-level effects, and Professors Murphy and Topel have not identified any plausible candidates for differential effects across adjacent quarters.

Professors Murphy and Topel also do not consider the fact that clustering is a problem of small samples in terms of both the number of clusters that are included in the analysis and the number of observations per cluster. Assume that several clusters are subjected to the same treatment effect, but, as is required for cluster analysis to be useful,

¹⁷ Wooldridge, 2003, *op. cit.*, p. 134.

each cluster is affected by a distinct group-level common variable that is unobserved. In this case, indicator variables for the cluster will account for the cluster-specific effects, with the efficacy of the cluster variables in dealing with the cluster problem rising as the number of clusters increases. The number of clusters identified by Professors Murphy and Topel is in the hundreds, which is far more than the number that econometricians normally would regard as creating a potential problem.¹⁸

In this case, one can also have statistical problems if the number of observations in each cluster differs so that the sampling error differs among clusters. Substantial disparity in sample sizes among groups can affect the efficiency of the estimate of a cluster effect and cause heteroskedasticity across groups. But in this case, the number of observations in each cluster also is large. As a result, the impact of heteroskedasticity is small. With large sample sizes within clusters, the mean value of the dependent variable within each cluster is a very precise estimate of the true mean, regardless of whether the error terms in the observations in each cluster have the same variance.¹⁹

One underlying factor that gives rise to the clustering problem is unobserved influences on outcomes at the group level. “Observations within a cluster are thought to be correlated as a result of an unobserved cluster effect.”²⁰ But, as explained above, this within-cluster effect can be taken into account by introducing fixed effects for each cluster and other variables that account for differences within a cluster. Equations (1)

¹⁸ Angrist and Pischke, *op. cit.*, whimsically state that 42 is the magic number of clusters that is sufficient to stop worrying about the distribution of errors. Of course, no magic solution exists, but the effects of violating the standard assumptions about the distribution of errors declines as the number of clusters increases.

¹⁹ Wooldridge, 2003, *op. cit.*, p. 136.

²⁰ Wooldridge, 2002, *op. cit.*, p. 229.

and (2) are regressions in which the treatment is an independent variable, but neither indicator variables for the clusters nor independent variables that might have a common effect within a cluster enter the regression. By comparison, the regression equations that I have estimated include indicator variables for iPod classes and capacities, other characteristics of products (e.g., cost), and separate indicator variables for several treatment effects (different competitive conditions in the market). Thus, the condition for clustering to be a problem because of unobserved common effects is not present.

The important point to emphasize is that *none* of the problems giving rise to a clustering adjustment is present in the iPod transactions data. First, there is no evidence that the residual errors are correlated within a group of transactions for a given model of iPod in a given calendar quarter. Second, the regressions on iPod transactions were not a sample of types of iPods, but are based on all transactions. Thus, the iPod data require no correction to adjust for sampling. Third, even if the transactions data were a sample, the sample size within each group of transactions for each type of iPod is large, as is the number of such groups. The magnitude of cluster effects diminishes with sample size, and these sample sizes are large enough to cause the effect of clustering to become unimportant. Fourth, variables to account for differences among these groups of transactions are present in the data set and are included in the regressions.

The final question is what harm can arise from using an inappropriate technique for adjusting the data when the data set does not fit the conditions that would make the adjustment appropriate. The problem is that if there is no clustering effect, the standard procedure for “improving” the estimates of the standard errors actually makes matters worse by causing an upward bias in the estimates of the standard errors of the regression

coefficients.²¹ For this reason, the proposal to apply cluster adjustments to a data set that does not actually contain clusters and that does not have a problem of confounding unobserved effects of iPod models with the relevant treatment effect (the introduction of iTunes 7.0) is not only unhelpful, but causes more harm than good in the quality of the regression estimates.

The procedure that Professors Murphy and Topel adopt to deal with the perceived problem of clustering collapses the residual errors for all transactions of a specific model of an iPod during a given calendar quarter into a single observation. This procedure vastly reduces the number of transactions observations, and thereby vastly reduces the number of degrees of freedom in the regression. This procedure leaves Professors Murphy and Topel with a regression that cannot reliably explain anything, all in pursuit of correcting a non-existent clustering problem.

The procedure that Professors Murphy and Topel use is not even one that is most recommended by econometricians when clustering is a problem. In dealing with true cluster effects, econometricians recommend adding more variables and adjusting the standard errors of the regression coefficient upward by a factor that depends on the number of clusters and the number of observations per cluster.²² The former has been done in the regression equations in the *Noll Merits Report*, and the latter adjustment approaches zero as the number of clusters and observations grows large. Thus, although the specifications of my regression equations were not adopted to deal with cluster effects, these equations are more consistent with the standard methods for coping with cluster effects than the methods advocated by Professors Murphy and Topel.

²¹ Angrist and Pischke, *op. cit.*, pp. 293-308.

²² Cameron and Miller, *op. cit.*, pp. 6-20.

RE-ESTIMATED DAMAGES MODEL

Separate damage equations were estimated for direct sale and reseller purchases. These equations calculate damages by comparing actual prices for the reference product with estimates of the prices that would have been charged in the “but-for” world in which the alleged anticompetitive act – the introduction of iTunes 7.0 that disabled Harmony – had not occurred. The regressions use the “before-after” method, in which the estimate of damages is based on the differences in prices of models of iPods before and after the occurrence of the anticompetitive act, as measured by a coefficient on a variable that takes the value of one for iPod models that included iTunes 7.0 or its successors.

[REDACTED]

The regressions that are used to calculate damages are estimated from Apple’s transactions data. Defendant’s economic experts, Professors Murphy and Topel, did not add or subtract any transactions in their analysis and instead used the same data that I used in the *Noll Merits Report*. The regressions use the logarithm of price from these transactions records as the dependent variable.

²³ Another feature that disabled Harmony, [REDACTED]. The iTunes 7.0 variable is set equal to one for these models.

The new regression equations differ from the regressions in the *Noll Merits Report* in ways discussed elsewhere in this report. First, a variable for time has replaced the logarithm of time. Second, the value of the “Harmony Blocked” variable has been set to one from the date that iTunes 4.7 was introduced until the end of the data period for models of iPods that did not use iTunes 7.0 or its successors. Third, the indicator variable for Harmony has been divided into the two versions of Harmony, with the first set equal to one from July 2004 until the end of the data period and the second set equal to one for all periods after April 2005. Fourth, the date on which iTunes became DRM-free has been set as January 6, 2009, rather than March 31, 2009. Fifth, the regression has been estimated using quantity weights, rather than frequency weights.

[REDACTED]

The reduced-form hedonic price equations that I have estimated are reported in Exhibits 3A (resellers) and 3B (direct purchasers). The damages are applicable to all iPod sales, including those excluded from the analysis. These price equations allow me to calculate damages for the transactions excluded from the regression as long as I use net sales revenues to account for returns.

To calculate damages from these equations, I start with the quantity and net sales

revenues for those models for which the iTunes 7.0 technology that disabled Harmony had been enabled for every transaction that occurred between the date that iTunes 7.0 was introduced and the date that iTunes became DRM-free. For the latter date, I use January 6, 2009, although the use of the January date causes damages to be underestimated for two reasons. First, iTunes customers continued to buy some encrypted recordings from iTunes beyond that date. Second, the lock-in effect remained in force for all iPod users who had bought encrypted downloads from iTunes in the past. These customers would not stop being locked in just because their most recent purchases were in a DRM-free format. The effect of continuing lock-in is to make the demand for iPods less price elastic, and thereby to cause the profit-maximizing price to be higher than otherwise would have been the case had iTunes 7.0 not prevented iPod users from buying music from RMS.

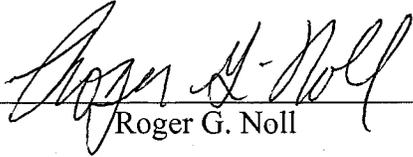
For each class/generation/family, total net sales quantity and total net sales amount are calculated. The estimated damage is calculated by applying the price overcharge percentage (calculated from the regression coefficients on the iTunes 7.0 variable) to the units sold in each class/generation/family.

For an individual transaction, damages can be calculated from the regression equations by multiplying the price overcharge percentage calculated from the iTunes 7.0 variable by the actual amount that was billed for the iPods that were purchased. If several models were purchased in a single transaction, total damages associated with that purchase are the sum of the damages for each iPod model, which is just the percentage overcharge multiplied by the total amount billed. Damages among customers will vary according to the price that they paid, with customers who received larger discounts receiving smaller damages.

[REDACTED]

[REDACTED]

I declare that the forging is true to the best of my knowledge and belief.



Roger G. Noll

Executed at Stanford California, on November 25, 2013.

DECLARATION OF SERVICE BY MAIL AND E-MAIL

I, the undersigned, declare:

1. That declarant is and was, at all times herein mentioned, a citizen of the United States and a resident of the County of San Diego, over the age of 18 years, and not a party to or interested party in the within action; that declarant's business address is 655 West Broadway, Suite 1900, San Diego, California 92101.

2. That on November 25, 2013 declarant served the attached REBUTTAL DECLARATION OF ROGER G. NOLL ON LIABILITY AND DAMAGES by depositing a true copy thereof in a United States mailbox at San Diego, California in a sealed envelope with postage thereon fully prepaid and addressed to the parties listed below.

3. That there is a regular communication by mail between the place of mailing and the place so addressed.

4. Also on November 25, 2013, I served the attached REBUTTAL DECLARATION OF ROGER G. NOLL ON LIABILITY AND DAMAGES on the parties in the within action by e-mail addressed as follows:

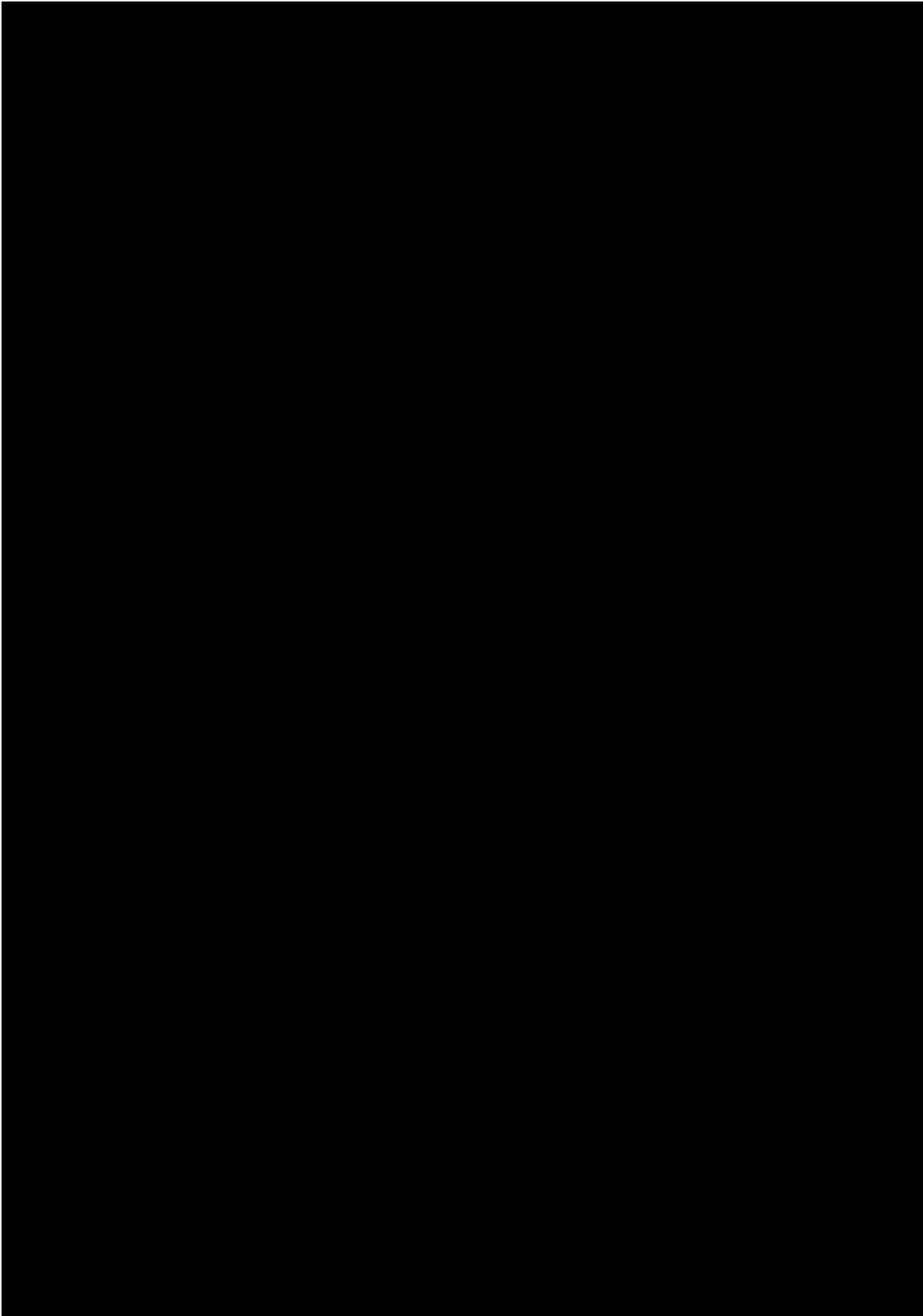
COUNSEL FOR DEFENDANTS:

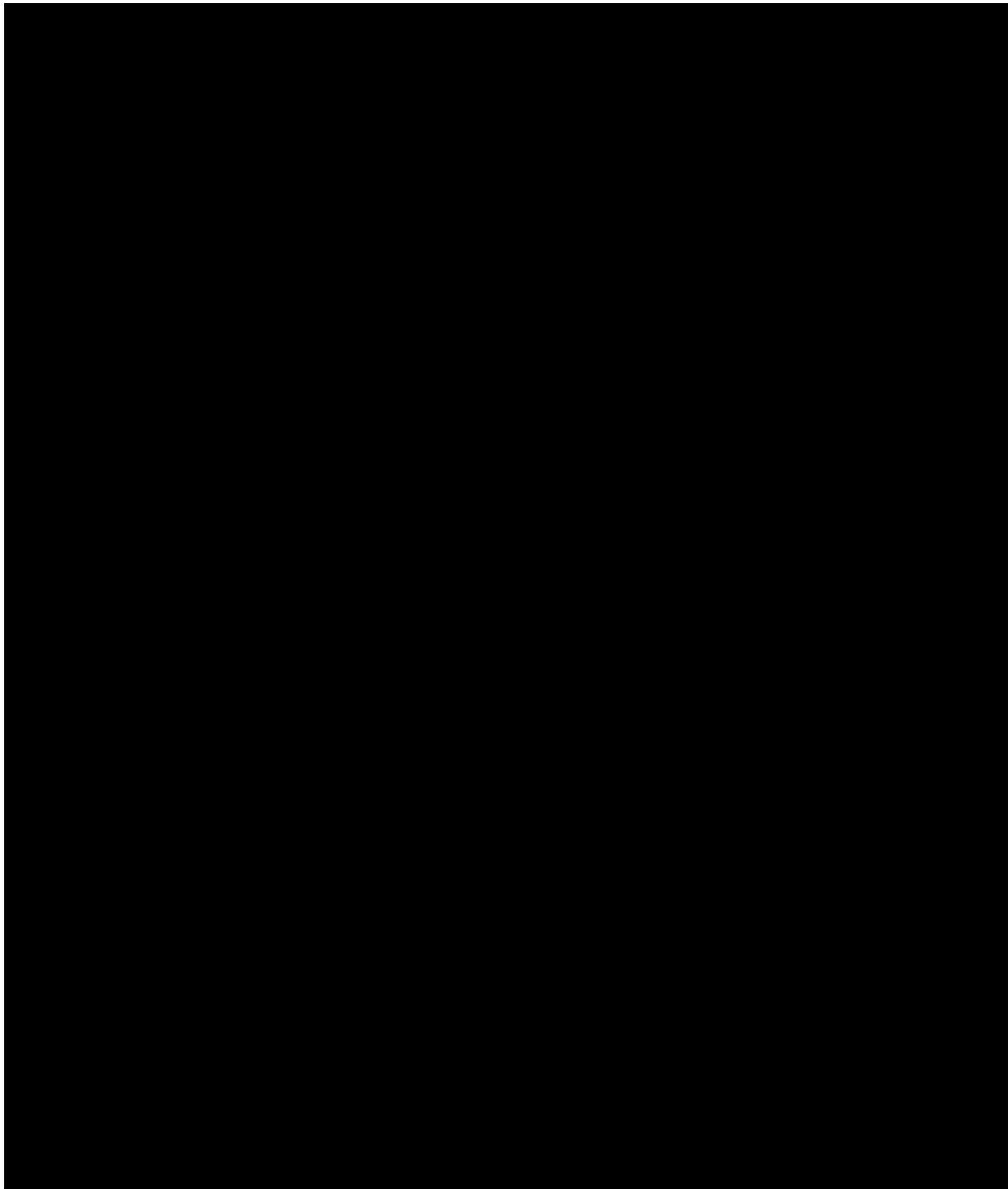
NAME	FIRM	EMAIL
Robert A. Mittelstaedt	Jones Day	ramittelstaedt@jonesday.com
Craig E. Stewart	Jones Day	cestewart@jonesday.com
Caroline Nason Mitchell	Jones Day	cnmitchell@jonesday.com
David C. Kiernan	Jones Day	dkiernan@jonesday.com

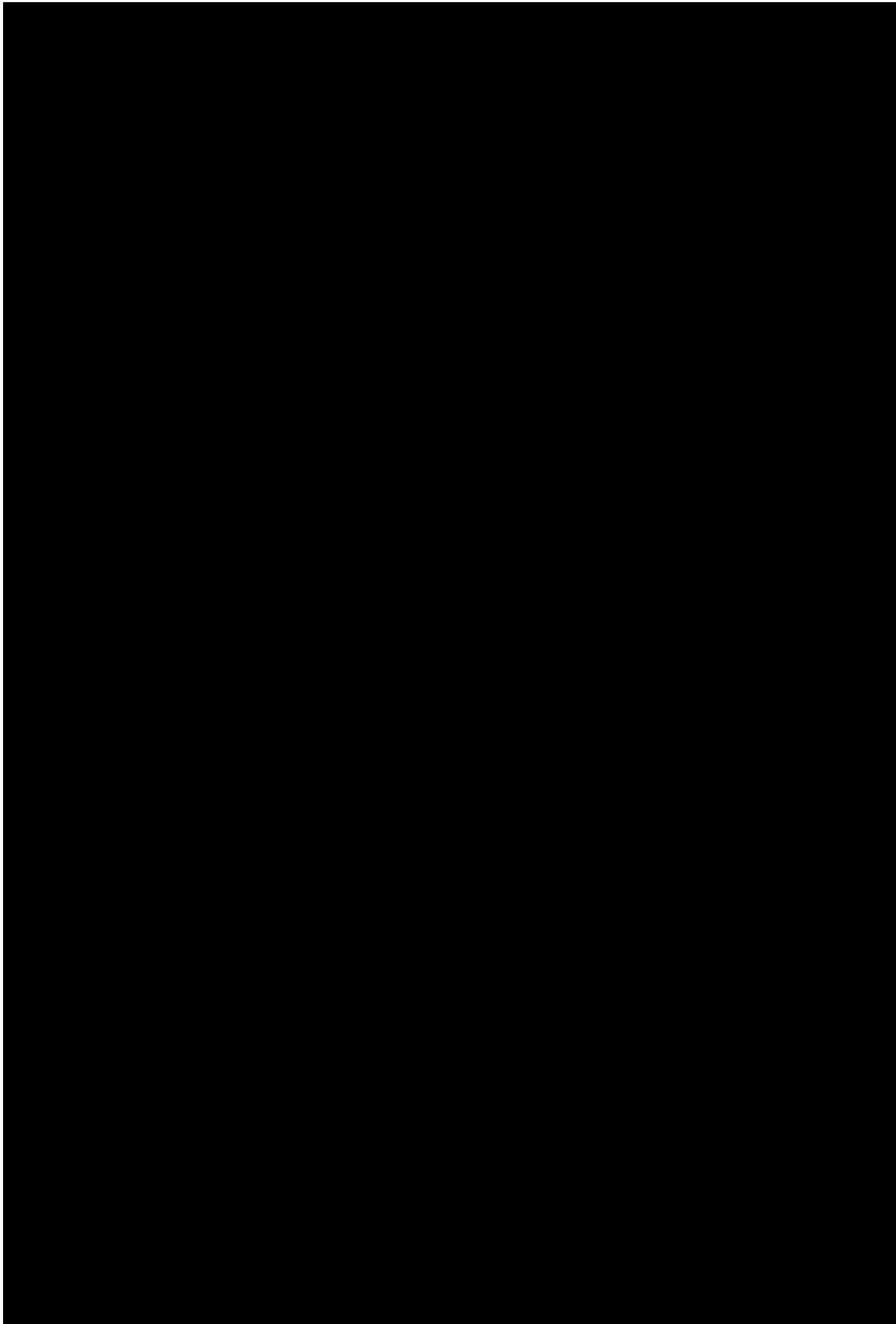
I declare under penalty of perjury that the foregoing is true and correct. Executed on November 25, 2013, at San Diego, California.

s/ Shonda L. Landry

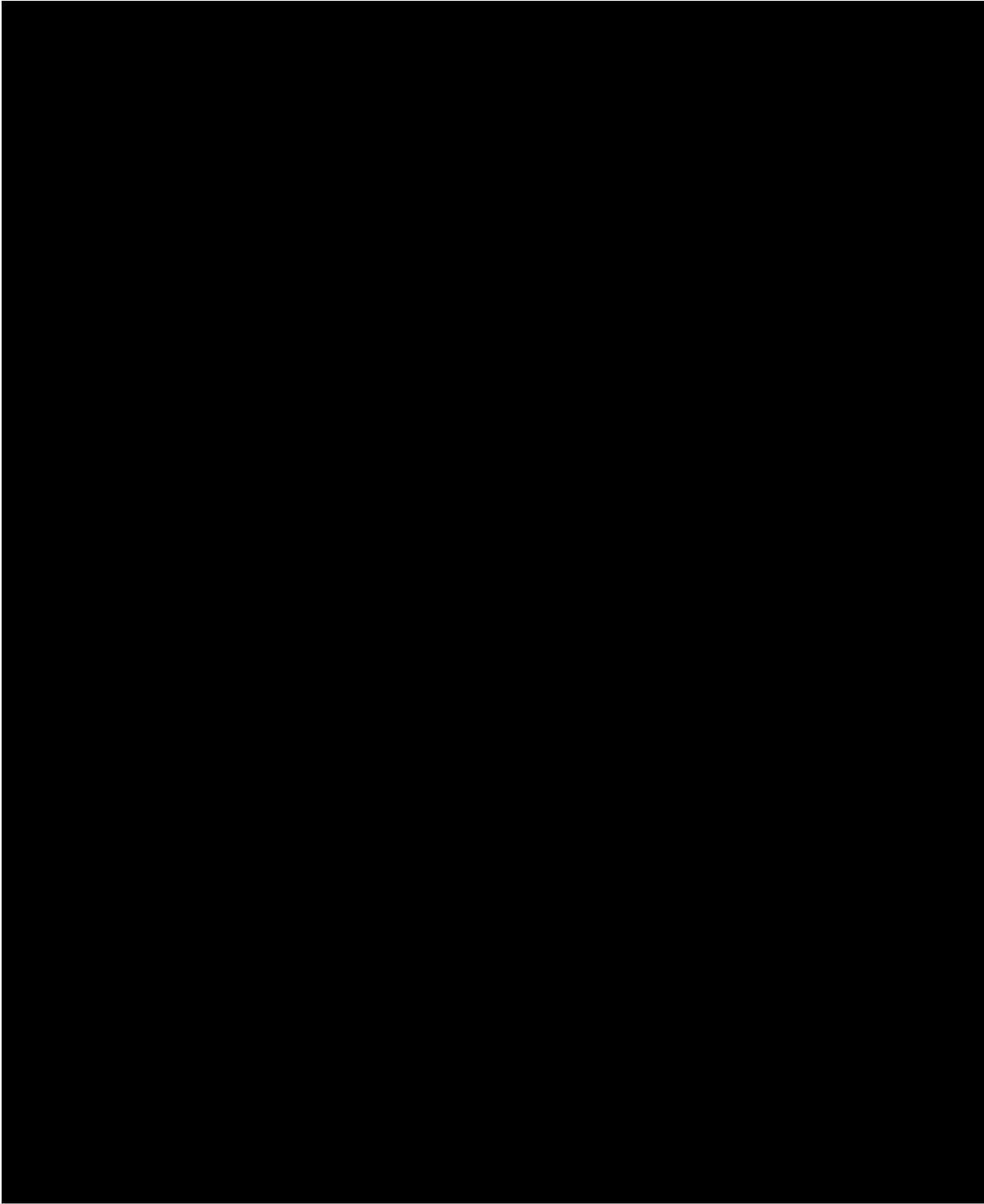
SHONDA L. LANDRY

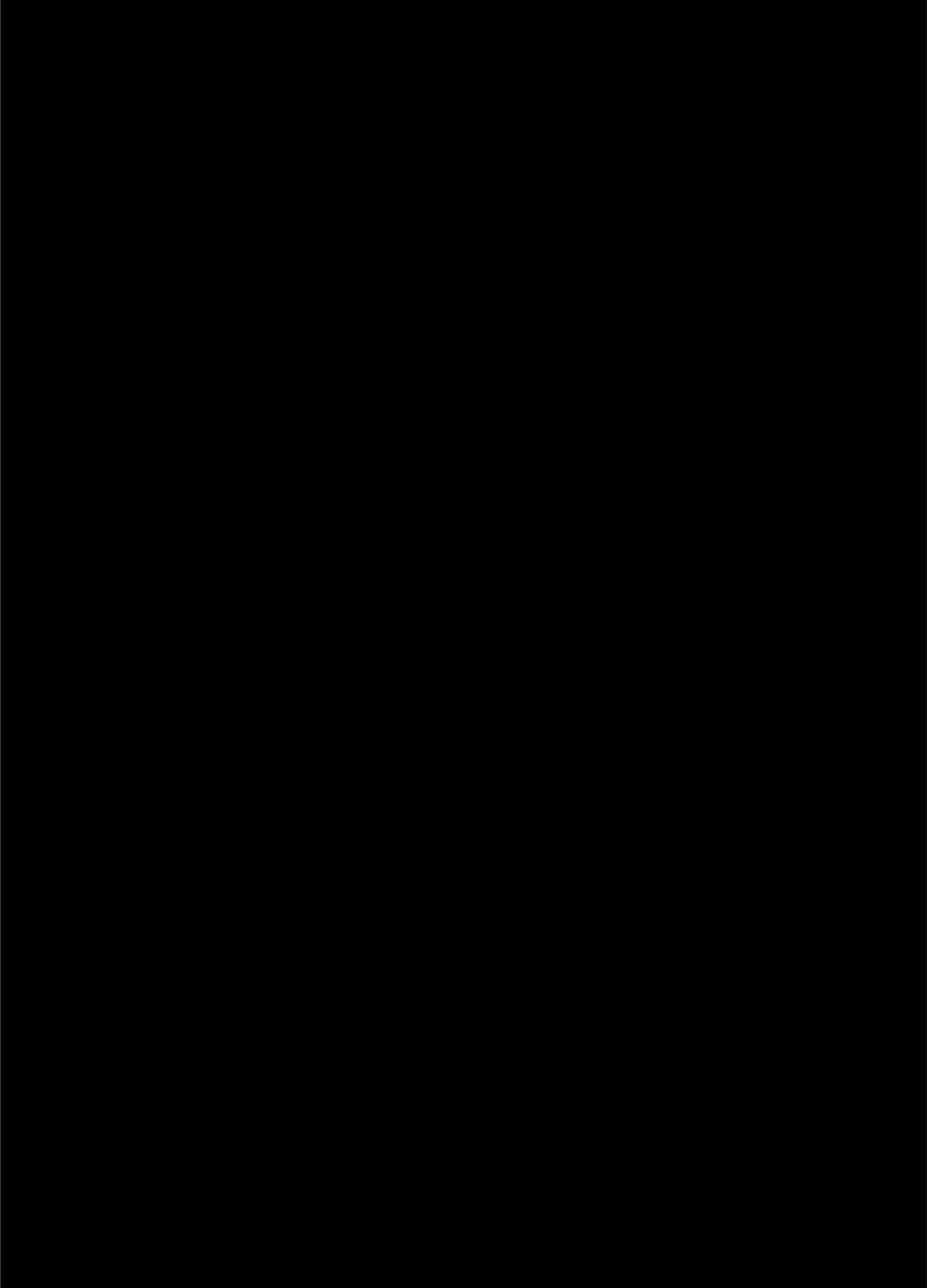


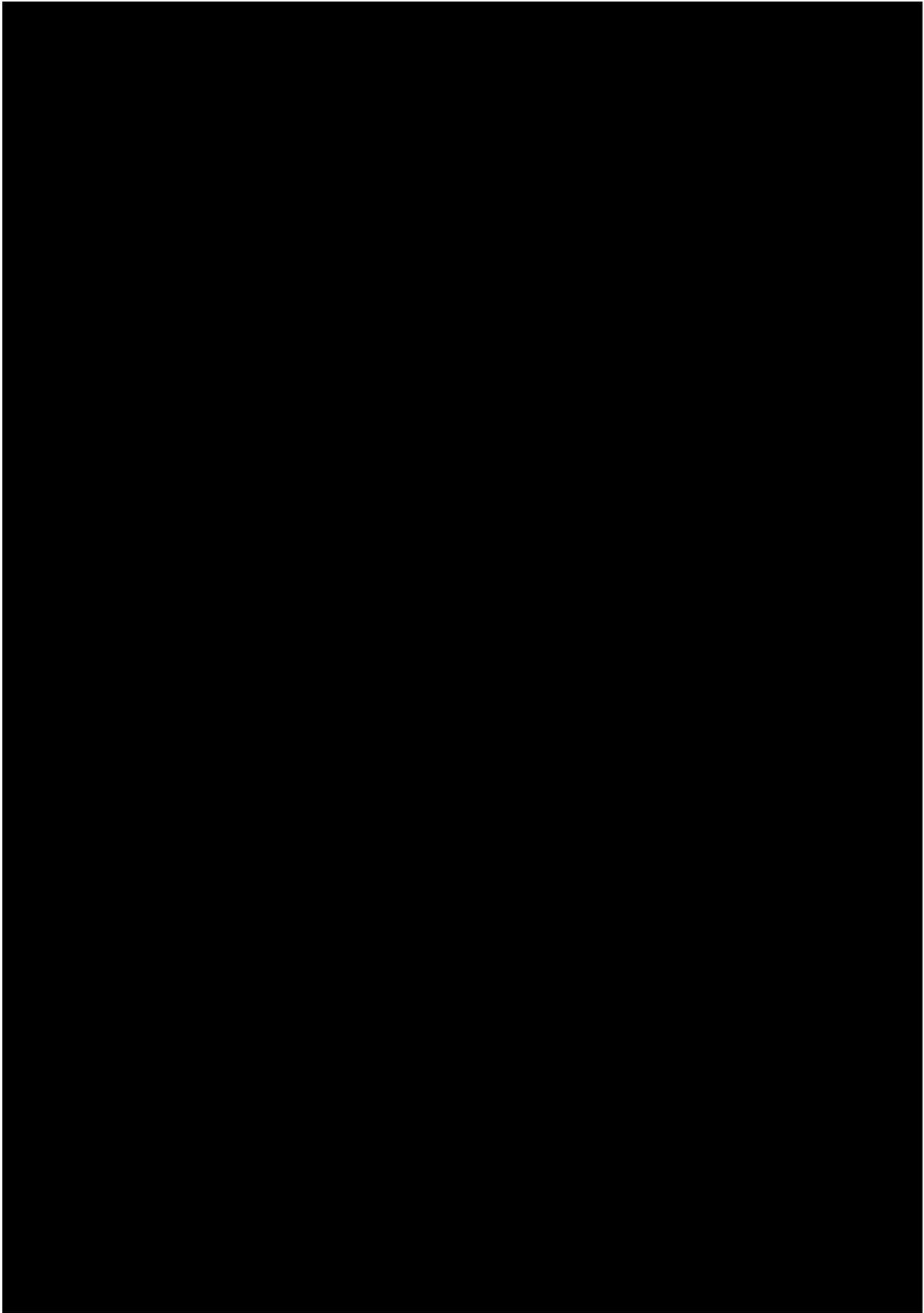




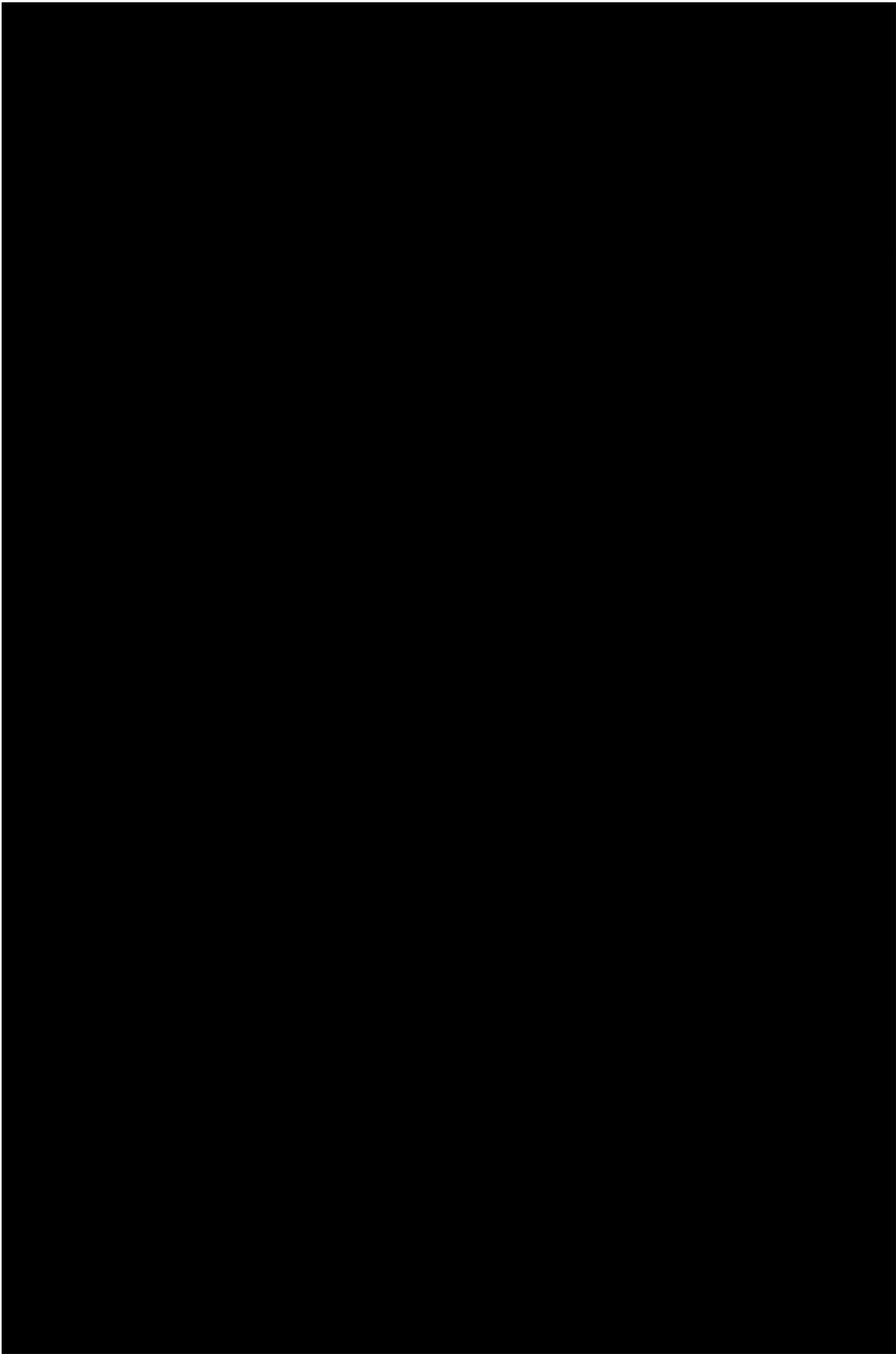
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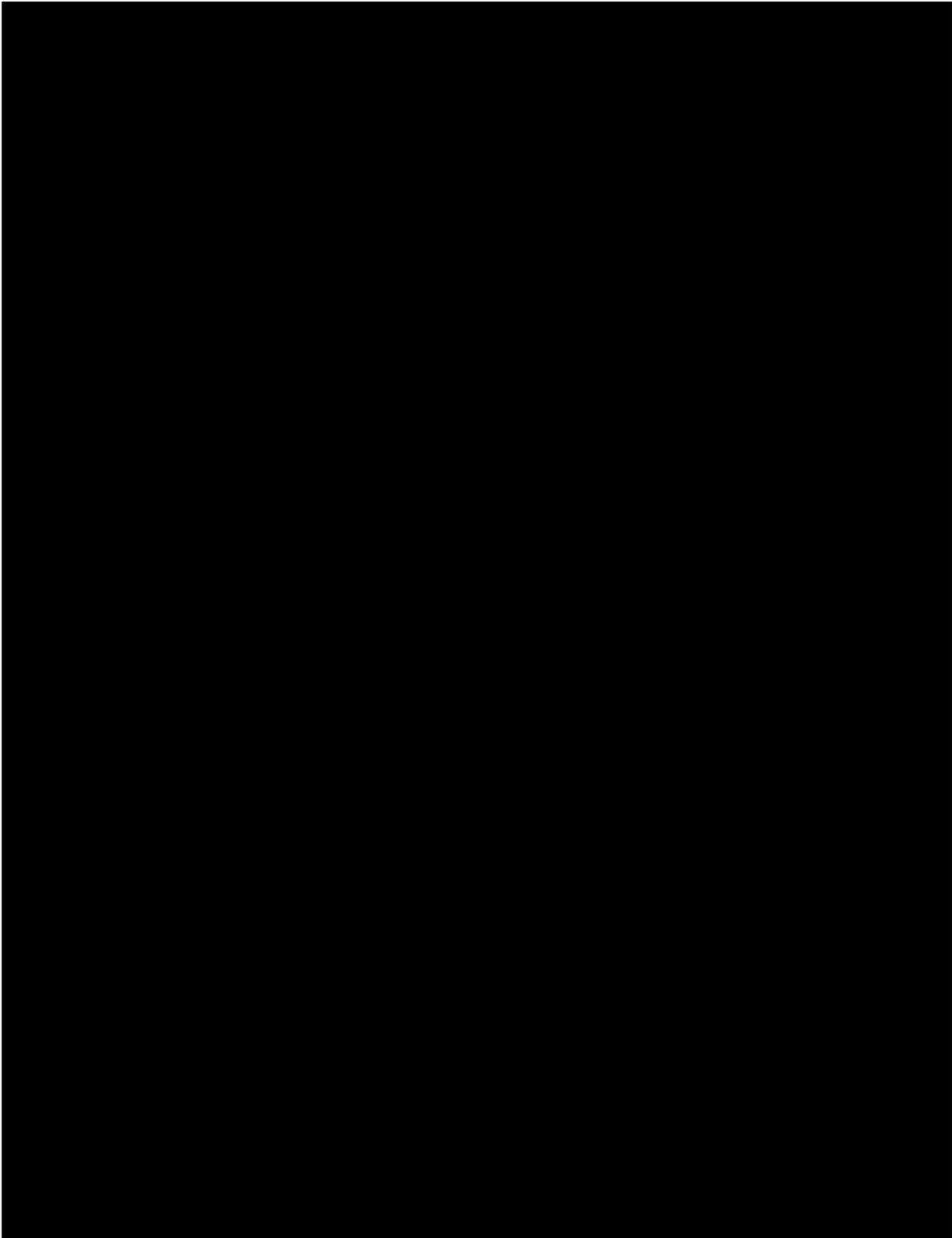




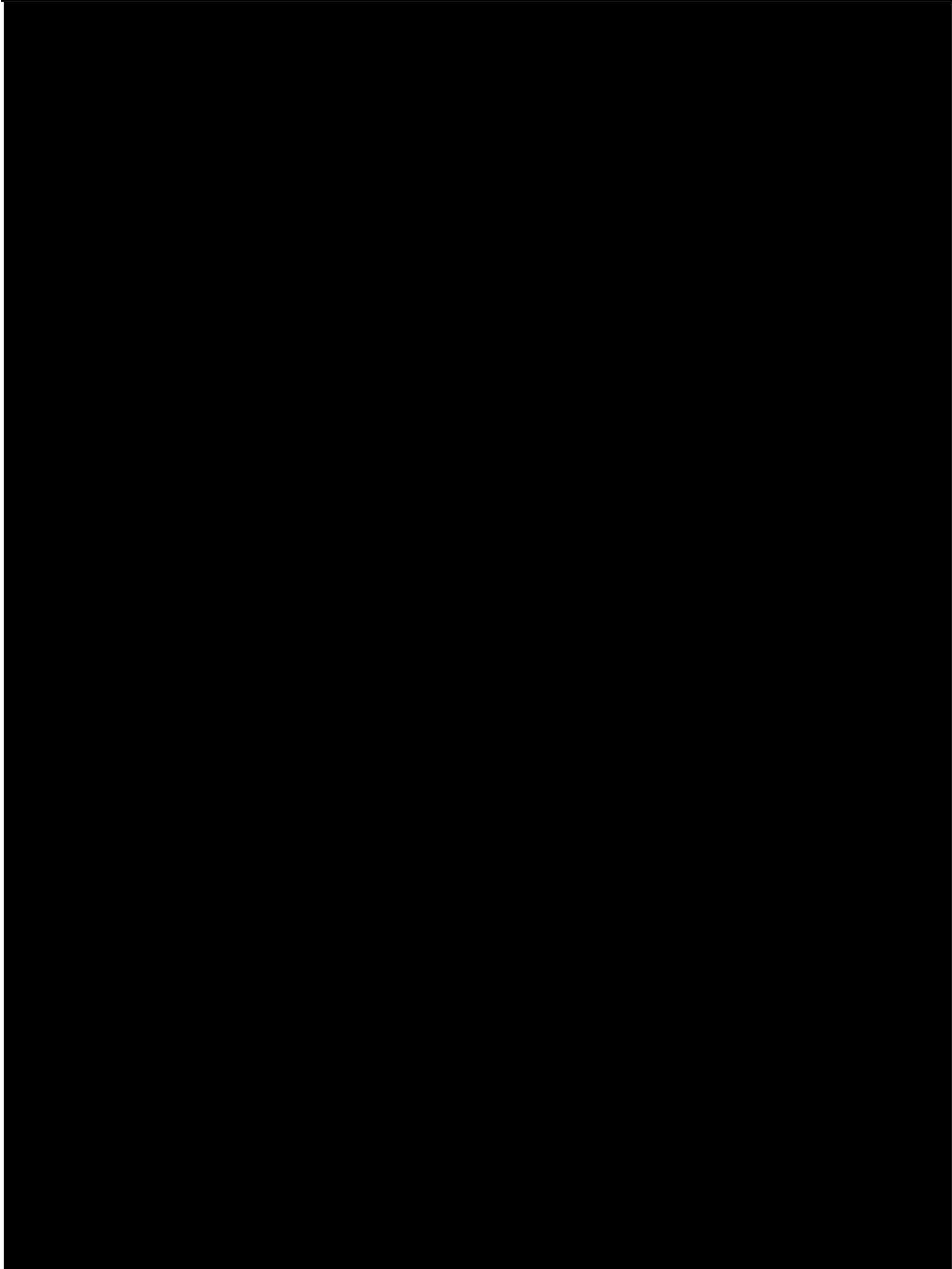
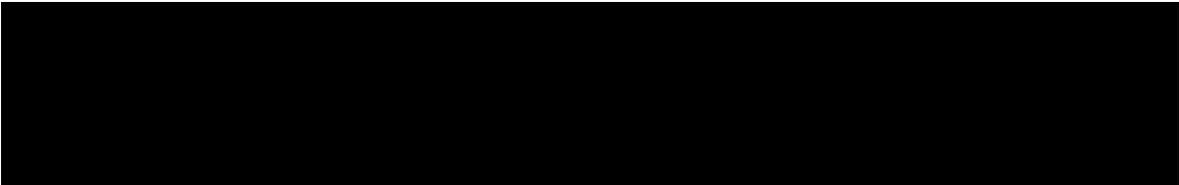
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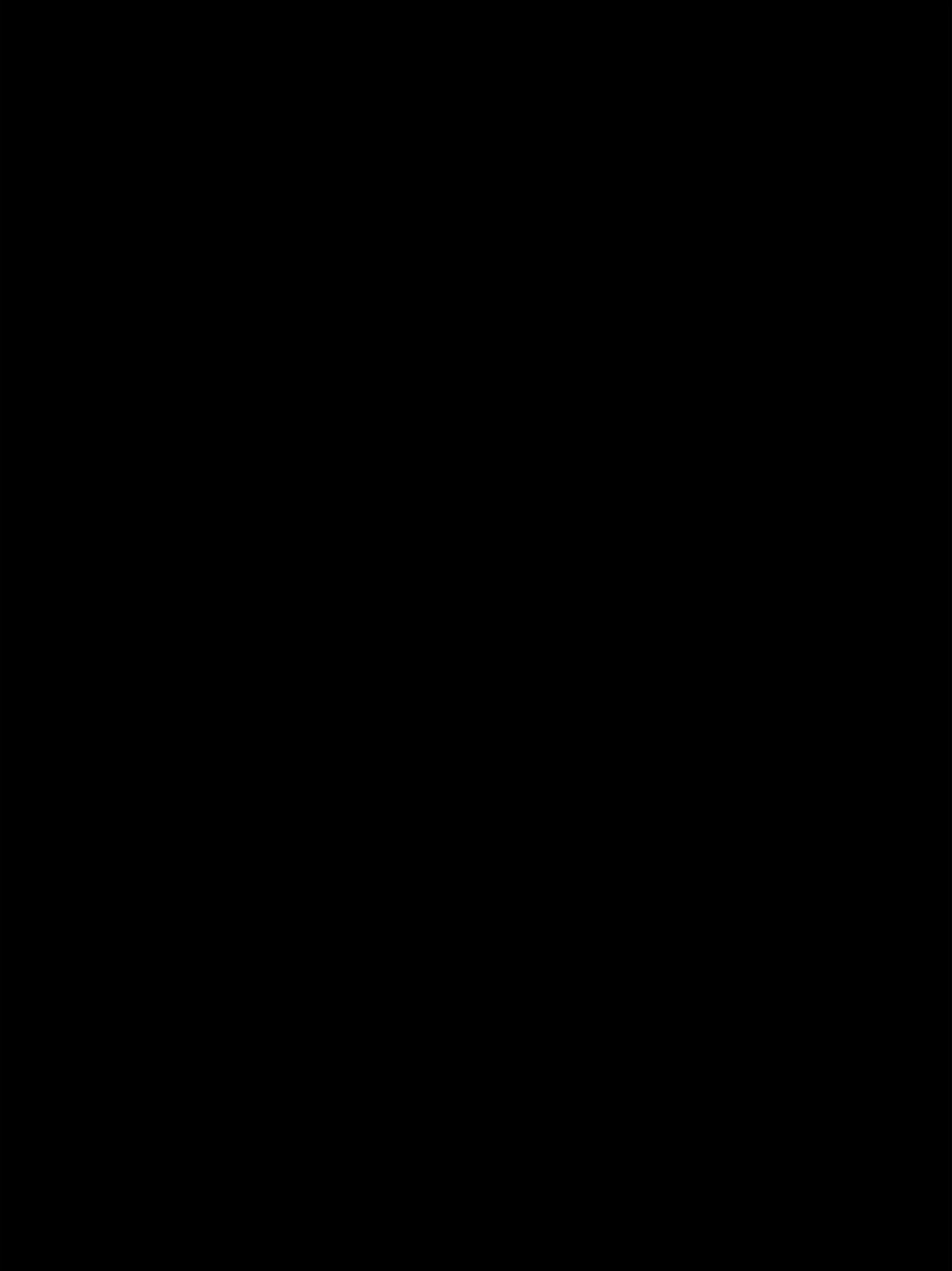


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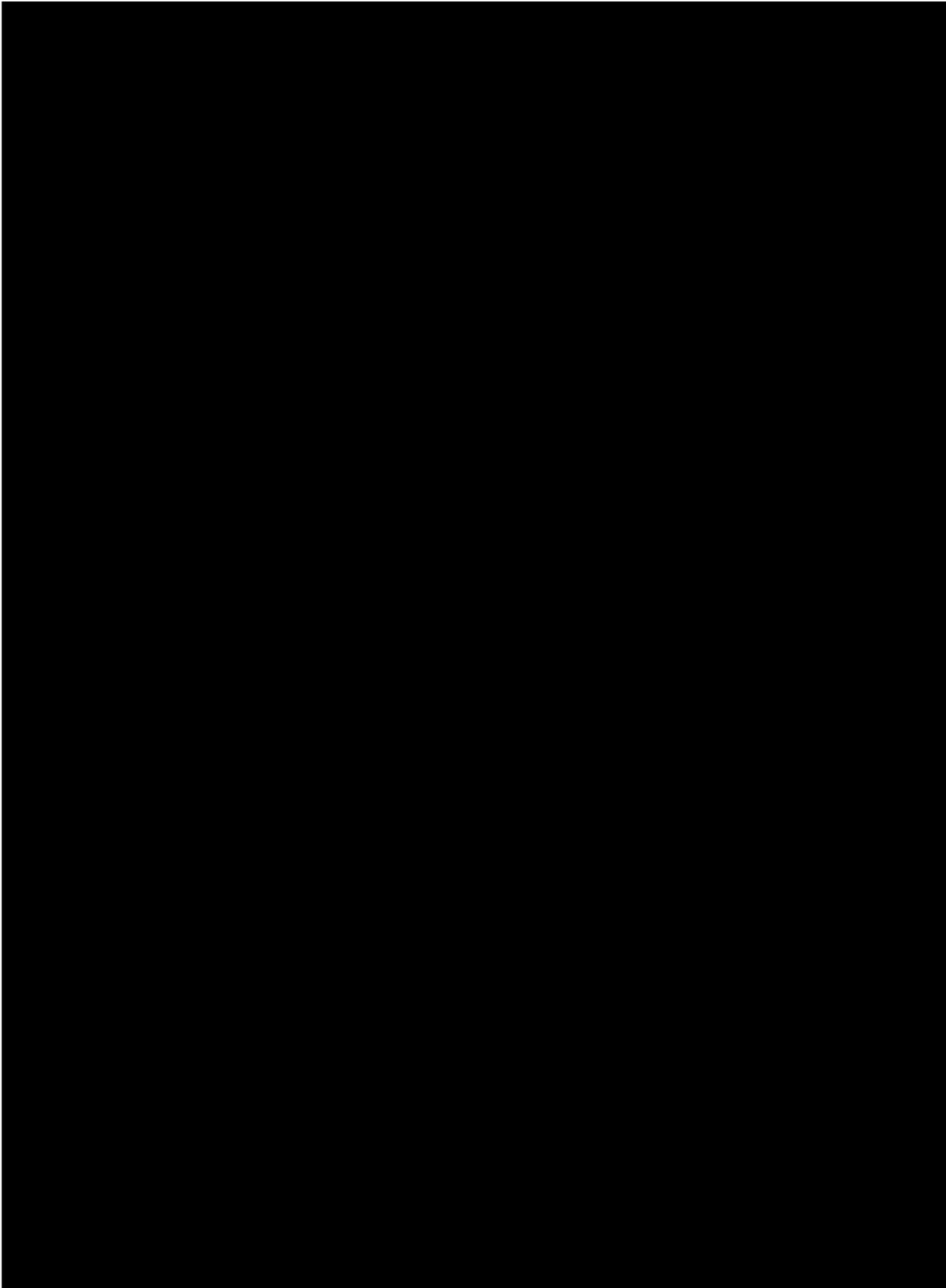


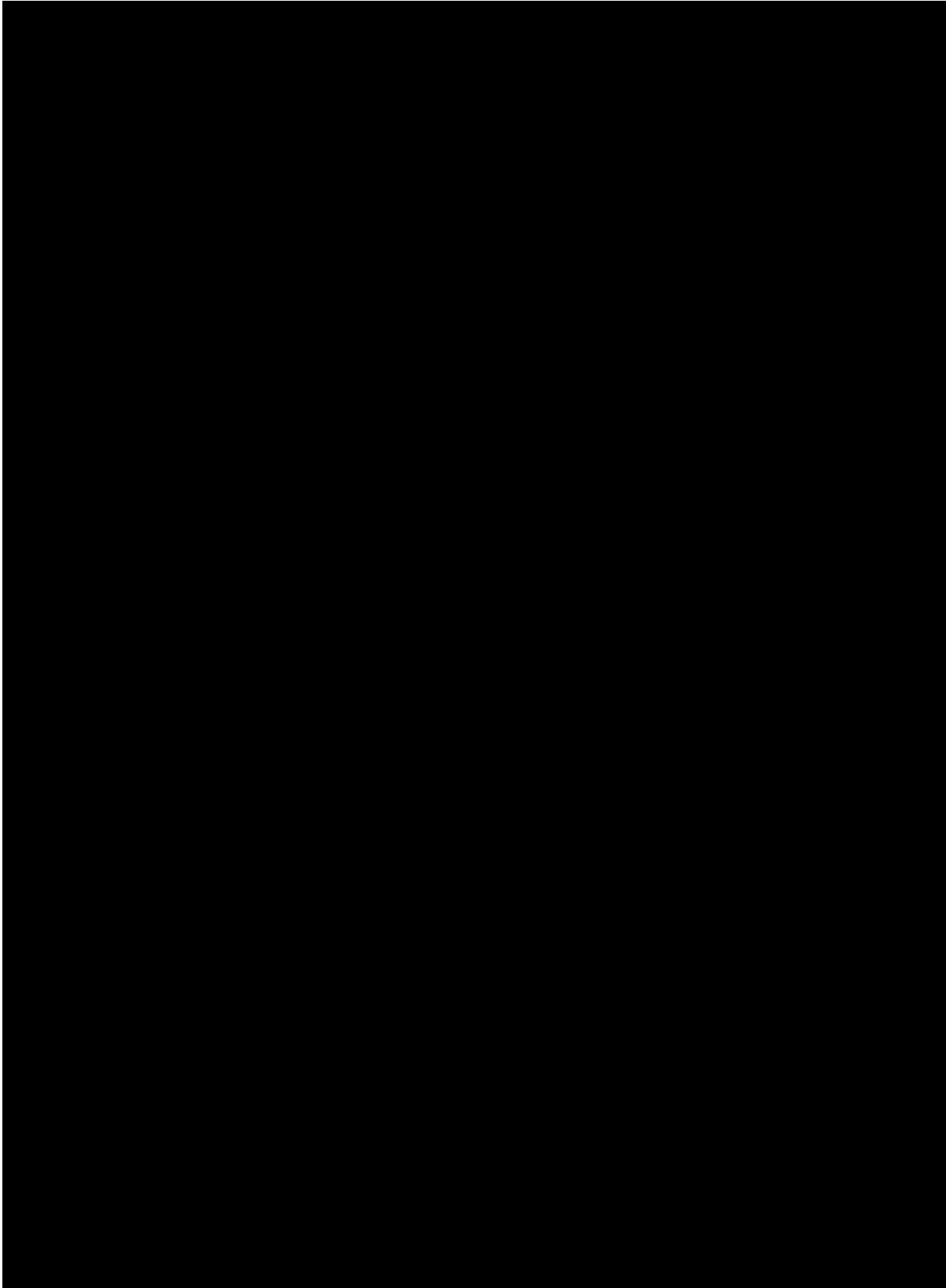
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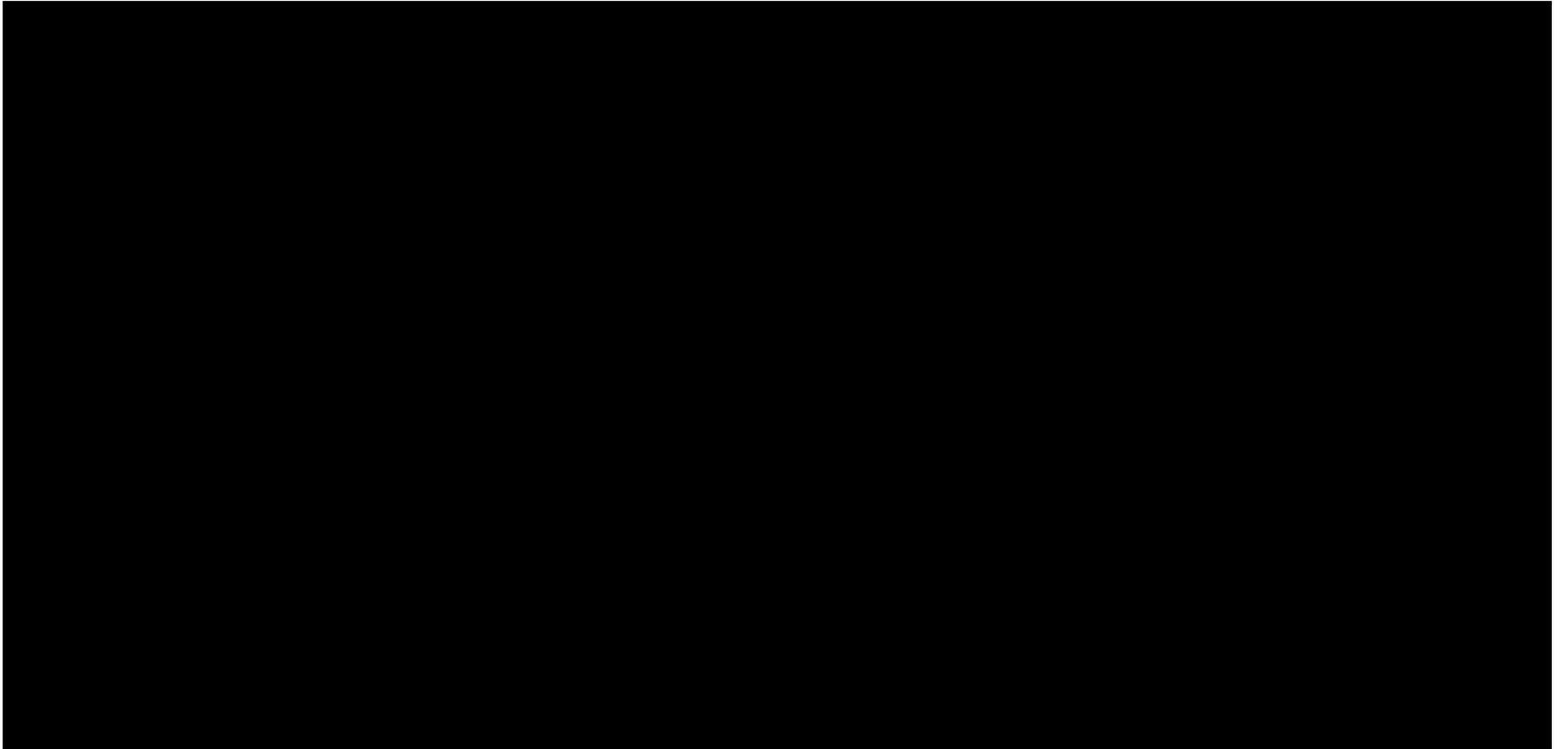


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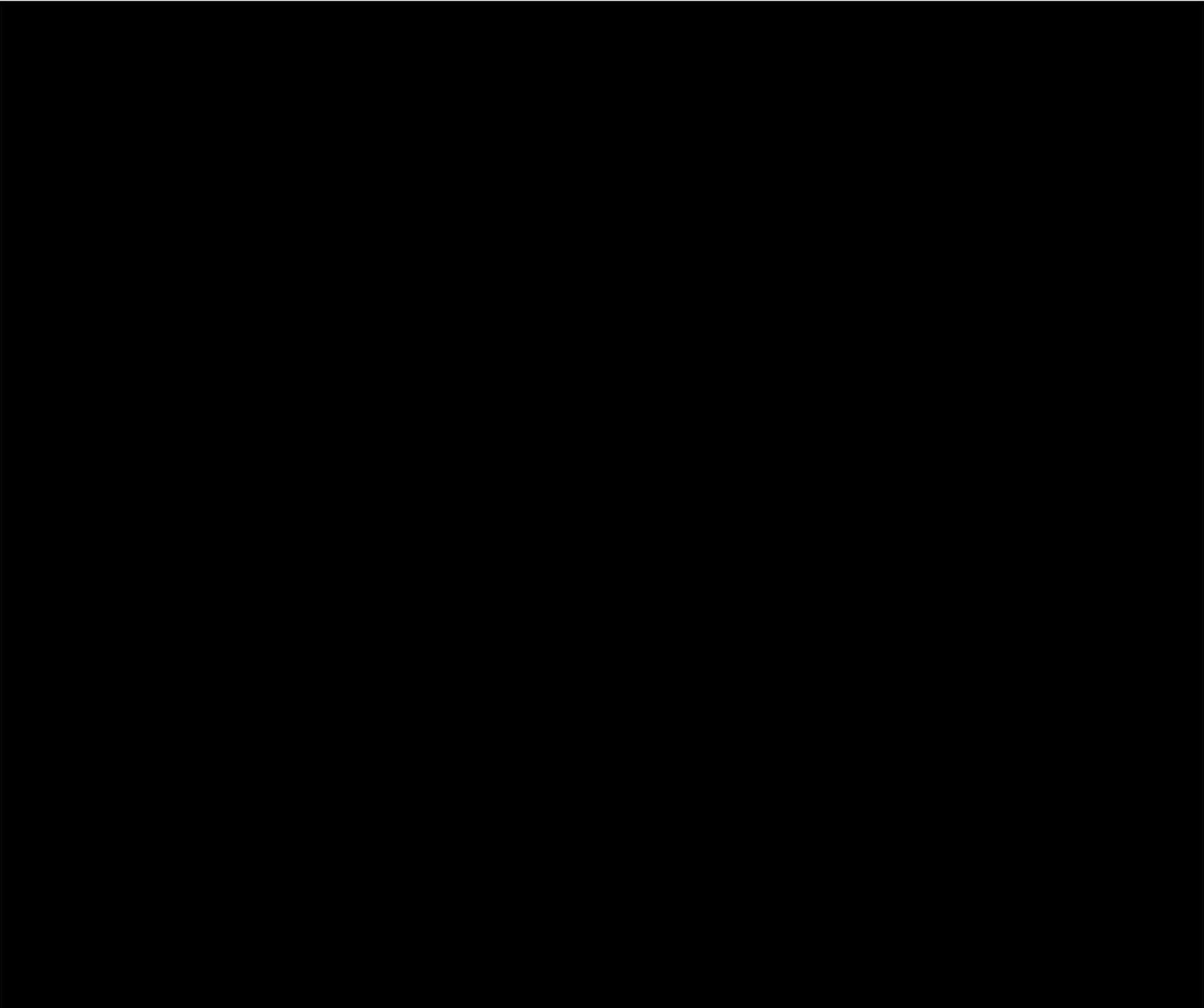




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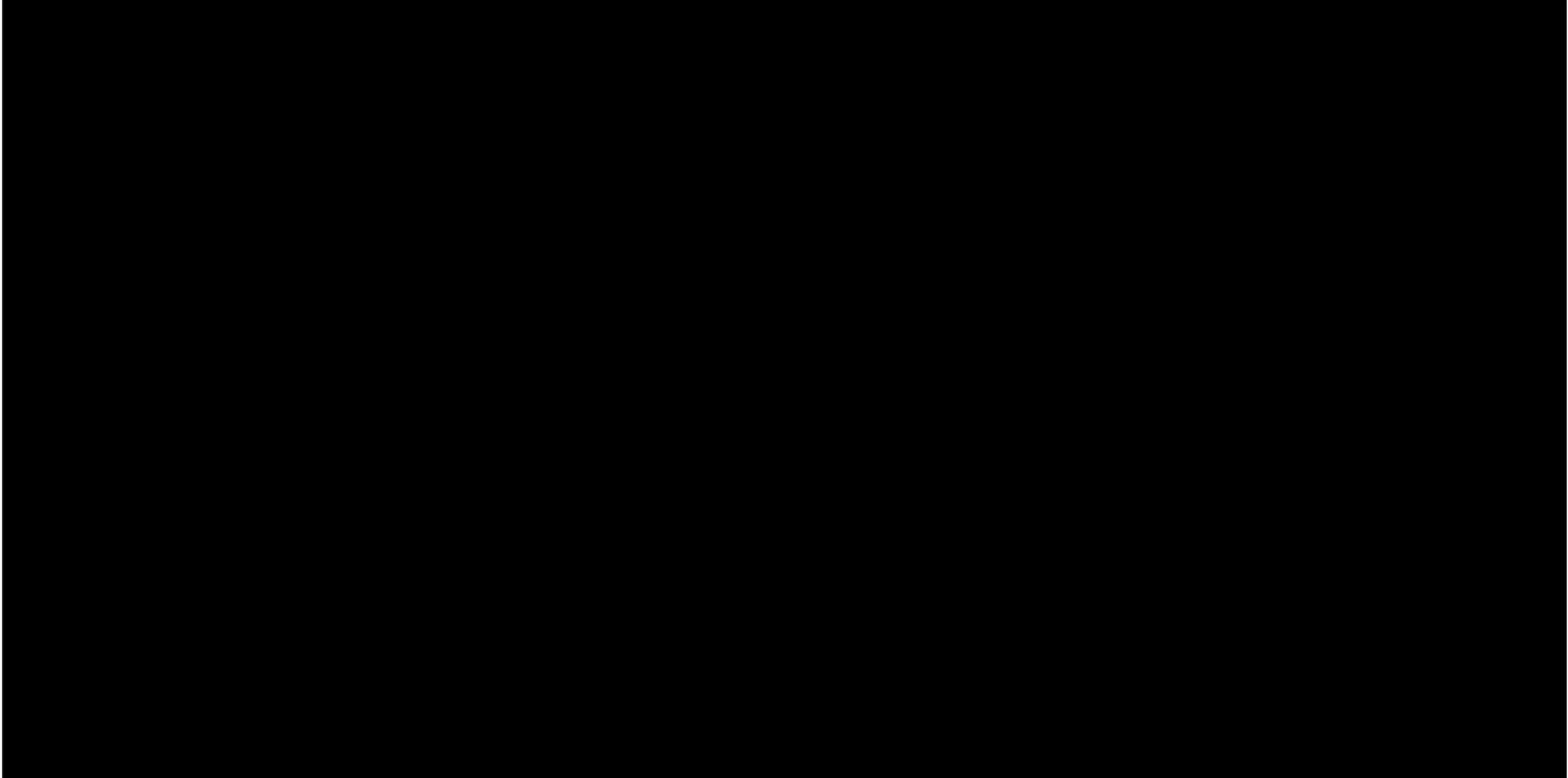


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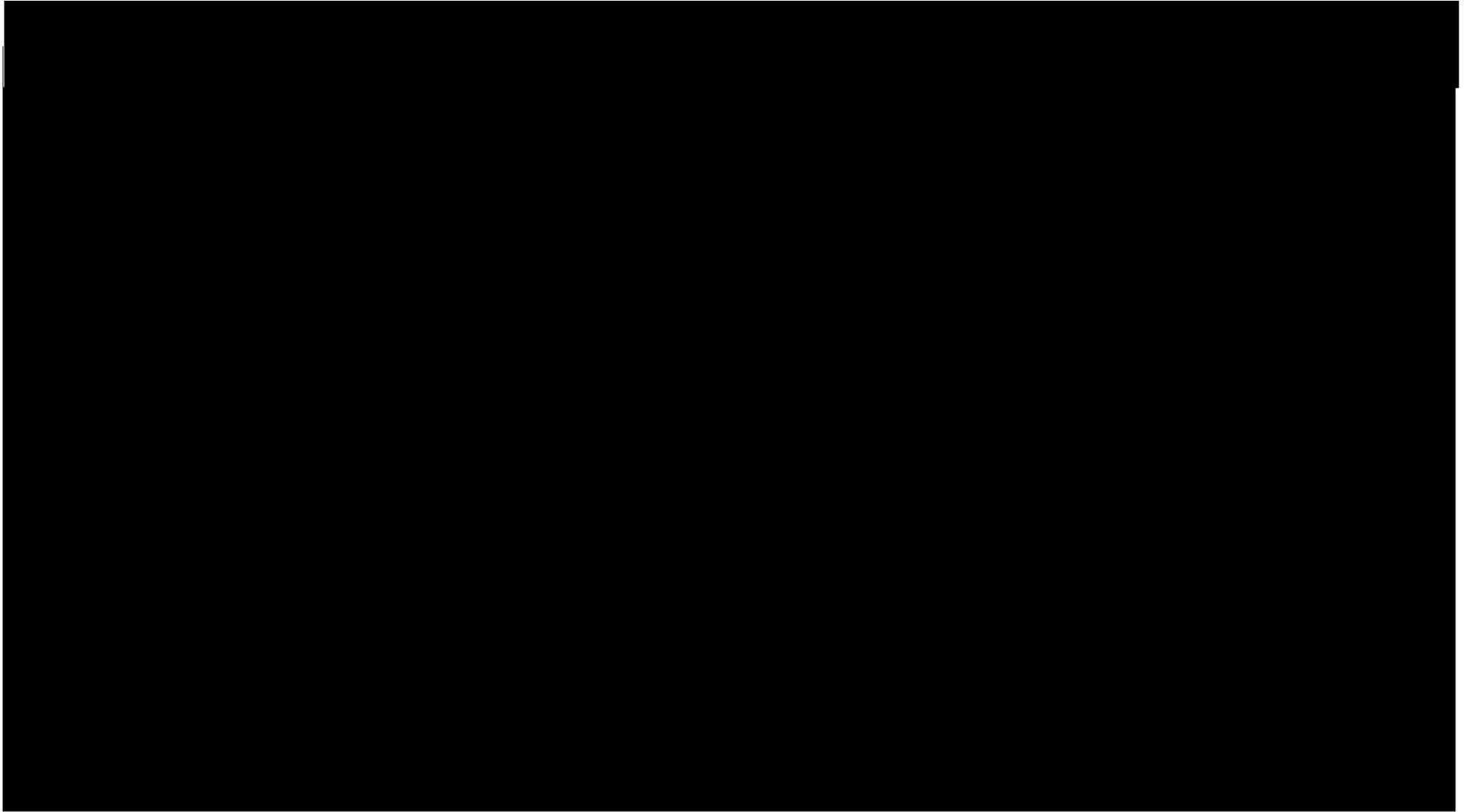


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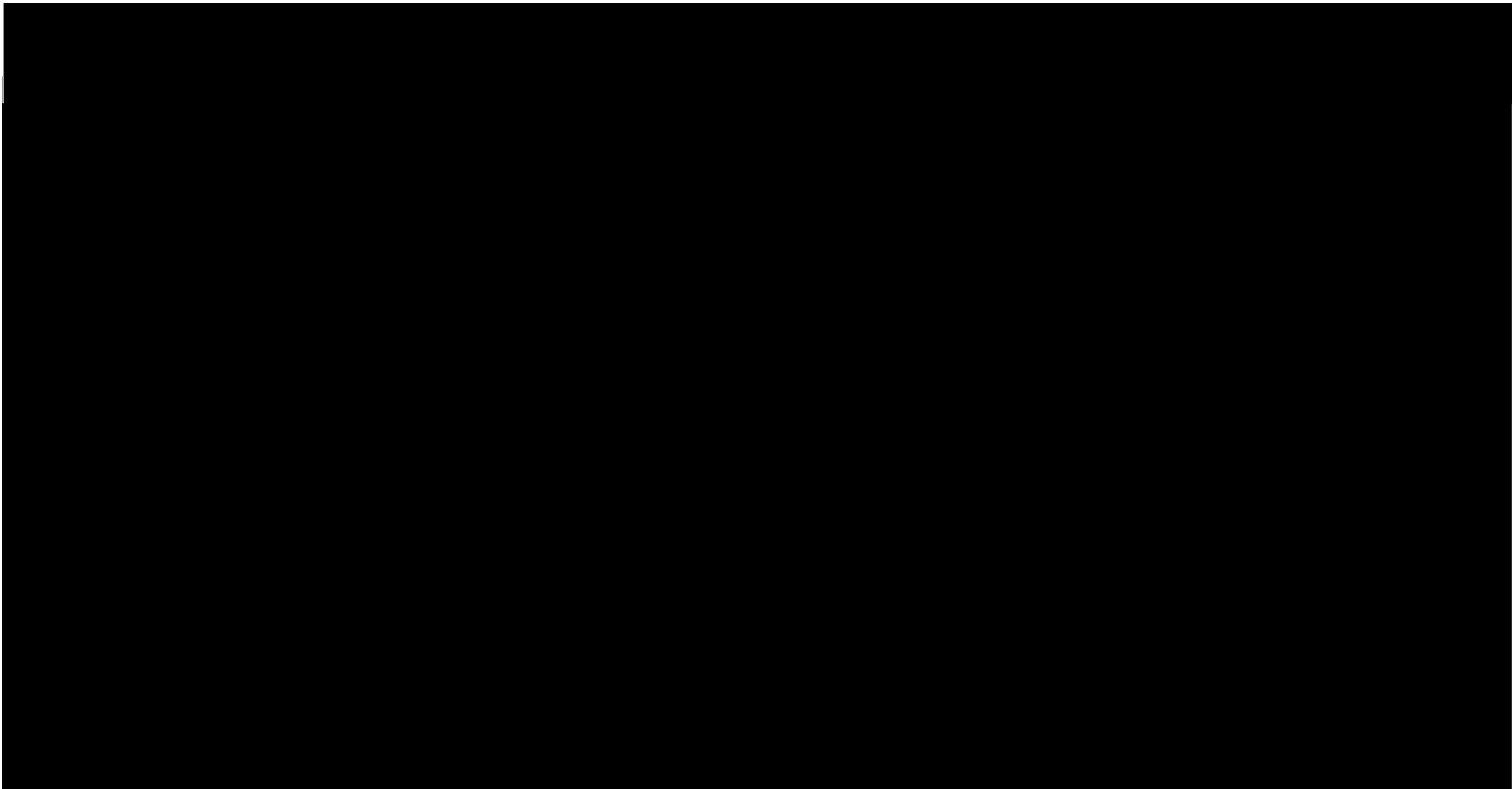
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APPENDIX A

CURRICULUM VITAE
ROGER G. NOLL

PERSONAL

Date and Place of Birth: March 13, 1940, Monterey Park, California

EDUCATION

East High School, Salt Lake City, Utah, 1958
B.S. (Math, Honors), California Institute of Technology, 1962
A.M., Ph.D. (Economics), Harvard University, 1965, 1967

SCHOLARSHIPS, FELLOWSHIPS AND AWARDS

National Merit Scholarship 1958-62
National Defense Education Act Fellowship 1962-66 (declined)
Harvard Prize Fellowship 1962-63
National Science Foundation Fellowship 1963-64
Guggenheim Fellow 1983-84
Rhodes Prize for Undergraduate Teaching, Stanford University, 1994
Distinguished Service Award, Public Utilities Research Center, University of Florida, 2001
Distinguished Lecture Award, Brookings-AEI Joint Center on Regulation and Markets, 2006
Alfred E. Kahn Distinguished Career Award, American Antitrust Institute, 2012
Distinguished Member Award, Transportation and Public Utilities Group, American Economic Association, 2013

POSITIONS HELD

Instructor, California Institute of Technology, 1965-67
Assistant Professor, California Institute of Technology, 1967-69
Senior Staff Economist, Council of Economic Advisers, 1967-68
Associate Professor, California Institute of Technology, 1969-71
Senior Fellow and Co-director, Studies in the Regulation of Economic Activity, Brookings Institution, 1970-73
Professor, California Institute of Technology, 1973-82
Visiting Professor, Graduate School of Business, Stanford University, 1976-77
Chair, Division of the Humanities and Social Sciences, California Institute of Technology, 1978-82
Reuben Gustavson Lecturer, University of Chicago, April 1981
Institute Professor of Social Sciences, California Institute of Technology, 1982-84
Donald Gilbert Memorial Lecturer, University of Rochester, December 1982
Fellow, Center for Advanced Study in the Behavioral Sciences, 1983-84
Professor of Economics, Stanford University, 1984-2006 (*Emeritus* 2006-)
Visiting Scholar, Hoover Institution, 1984-85
Professor by Courtesy, Department of Political Science, Stanford University, 1985-2006
Professor by Courtesy, Graduate School of Business, Stanford University, 1986-2006
Veblen-Clark Lecturer, Carleton College, May 1986
Director, Public Policy Program, Stanford University, 1986-2002
David Kinley Lecturer, University of Illinois, May 1987
Sunderland Fellow, Law School, University of Michigan, Fall 1988

Positions, cont'd

Morris M. Doyle Centennial Professor in Public Policy, Stanford University, 1990-2002
Jean Monnet Professor, European University Institute, Spring 1991
Associate Dean, Humanities and Sciences, Stanford University, 1991-92
Visiting Professor, University of California, San Diego, 1993
Visiting Fellow, Brookings Institution, 1995-96
Nonresident Senior Fellow, Brookings Institution, 1996-99
Director, American Studies Program, Stanford University, 2001-02
Visiting Scholar, London School of Economics, Spring 2001 and Spring 2002
Senior Fellow, American Antitrust Institute, 2002-
Director, Stanford Center for International Development, 2002-06
Kim Thomas Lecturer, Whittier College, 2010

TEACHING EXPERIENCE

Undergraduate: Introductory Economics, Intermediate Microeconomic Theory, Introduction to Econometrics, Antitrust and Regulation, Economic History of Medieval Europe, History of Economic Thought, Economic Policy Analysis, Economics of Sports, Political Economy of the West

Graduate: Antitrust and Regulation, Economic Policy Analysis, Applied Microeconomic Theory, Experimental Economics

RESEARCH INTERESTS

Antitrust and Regulation, Technology Policy, Political Economics, Political Economy of Law

MEMBERSHIP ON BOARDS AND COMMITTEES

President's Task Force on Communications Policy (CEA Staff Representative), 1967-68
President's Task Force on Suburban Problems, 1968
President's Committee on Urban Housing, 1968
President's Task Force on Public Broadcasting, 1968
Department of Commerce Technical Advisory Board Panel on Venture Capital, 1968-69
Committee on the Multiple Uses of the Coastal Zone, National Council on Marine Resources and Engineering, 1968
Secretary, President's Interagency Task Force on Income Maintenance, 1968
Task Force on Application of Economic Analysis to Transportation Problems, National Research Council, 1970-73
Committee on Technological Forecasting on Behalf of the Environment, Office of Science and Technology, 1970-71
Board of Economic Advisers, Public Interest Economics Foundation, 1974-84
Executive Committee, Caltech Environmental Quality Laboratory, 1970-71
Faculty Board, Caltech, 1974-76
Advisory Commission on Regulatory Reform, Senate Committee on Government Operations, 1975-77
Chair, Fourth Annual Telecommunications Policy Research Conference, 1975-76
Committee on Satellite Communications, National Academy of Sciences, 1975-76
Advisory Council, Jet Propulsion Laboratory, 1976-82
Chair, Committee to Monitor the Desegregation Plan of the Los Angeles Unified School District, Los Angeles Superior Court, 1978-79

Boards, cont'd

Advisory Council, National Aeronautics and Space Administration, 1978-81
Advisory Council, National Science Foundation, 1978-89
Board of Advisers, National Institute of Economics and Law, 1978-84
Research Advisory Board, Committee for Economic Development, 1979-82
President's Commission for a National Agenda for the Eighties, 1980
Board of Directors, Economists, Inc., 1981-
Review Panel, NSF Regulation and Public Policy Program, 1981-84
Board of Editors, Journal of Economic Literature, 1981-90
Advisory Board, Solar Energy Research Institute, 1982-91
Board of Directors, Cornell Pelcovits and Brenner, Inc., 1982-1988
Chair, Advisory Panel on Information Technology R&D, Office of Technology Assessment, 1983-84
Supervisory Board of Editors, Information Economics and Policy, 1982-88
Advisory Committee on Integrated Environmental Management Program, Environmental Protection Agency, 1983-85
Commission on Behavioral and Social Sciences and Education, National Research Council, 1984-90
Advisory Panel, NSF Policy Research and Analysis Division, 1984
Director, Program on Regulatory Policy, Stanford Institute for Economic Policy Research, 1984-
Panel on Clean Air, Science Advisory Board, Environmental Protection Agency, 1985-86
Board of Editors, Review of Economics and Statistics, 1985-2002
Contributing Editor, Regulation, 1986-93
Energy Research Advisory Board, Department of Energy, 1986-89
President & Chairman of the Board, Telecommunications Policy Research Foundation, 1986-87
Coordinating Editor, Information Economics and Policy, 1988-92
Board of Directors, International Telecommunications Society, 1988-92
Advisory Board of Editors, Journal of Risk and Uncertainty, 1988-
Acid Rain Advisory Committee, Environmental Protection Agency, 1990-91
Secretary of Energy Advisory Board, 1990-95
International Board of Editors, International Journal of the Economics of Business, 1993-
Faculty Senate, Stanford University, 1993-95, 98-02, 04-06
California Council on Science and Technology, 1995-2001
Panel on Universities, President's Committee of Advisors on Science and Technology, 1996
Committee on Intellectual Property and the Information Infrastructure, National Research Council, 1997-9
Board of Editors, Journal of Sports Economics, 1999-
Board of Associate Editors, Economics of Governance, 1999-
Board of Advisors, American Antitrust Institute, 2000-
Board on Science, Technology and Economic Policy, National Research Council, 2000-2006
Committee on Universal Postal Service, National Research Council, 2008

SPONSORED RESEARCH

"Opinions of Policemen." International Association of Chiefs of Police, 1969
"Studies in the Regulation of Economic Activity." Brookings Institution and Ford Foundation, 1970- 3
"Government Policies and Technological Innovation." National Science Foundation National R&D Assessment Program, 1973-4
"The Social Consequences of Earthquake Prediction," National Aeronautics and Space Administration, 1974-6
"Nuclear Safety Regulation." National Science Foundation RANN Program, 1975-7
"The Public Television Station Program Cooperative." National Science Foundation RANN Program, 1975-7
"The Station Allocation Game." Federal Communications Commission, 1977
"Energy Policy Studies." Various donors, 1978-84

Sponsored Research, cont'd

"Economics of Oil Leasing" and "Issues in Utility Pricing." Department of Energy, 1978-9
"The Economics of Boxing, Wrestling and Karate." California Athletic Commission, 1978
"Implementing Tradable Emissions Permits." California Air Resources Board, 1979-82
"Social Science and Regulatory Policy." National Science Foundation, 1980-2
"The Political Economy of Public Policy." National Science Foundation and Center for Economic Policy Research, Stanford University, 1983-4
"SIEPR Program on Regulatory Policy." various donors, 1987-
"The Economics of Research Universities and Scholarly Communication." Brown Center for Education Policy, Brookings Institution, 1995-6
"Coordination of Regulatory Reform," Organization for Economic Cooperation and Development, 1996
"The Future of the Research University," Carnegie Foundation, 1996
"SCID Program in Economic Policy Reform," Various donors, 2002-06

CONSULTING

Special Assistant to the President, Ford Foundation, 1969
Space Technology Applications, Jet Propulsion Laboratory, 1969
Panel on the Abatement of Particulate Emissions, National Research Council, 1971
Sloan Commission on Cable Communications, 1971
President's Commission on Government Procurement, 1971
Senate Subcommittee on Antitrust and Monopoly, 1971-72
MCI, Inc., 1972-73, 1983, 1986
National Science Foundation, 1973, 1975
Department of Justice, Antitrust Division, 1974-77, 1979-81, 1993-97
Internal Revenue Service, 1976-77
RAND Corporation, 1974-82
Los Angeles Lakers, 1974-75
National Football League Players Association, 1974-76, 1987-93, 2008, 2010-
Office of Telecommunications Policy, 1975-77
National Basketball Association Players Association, 1975-76, 1987-88, 1994
Naval Ordnance Test Station, 1975
Commission on Law and the Economy, American Bar Association, 1977-78
Aspen Institute Program on Communications and Society, 1977
National Commission on Electronic Funds Transfer, 1977
Business Round Table, 1978
Federal Communications Commission, 1977-81
Food and Drug Administration, 1978
Carnegie Commission on the Future of Public Broadcasting, 1978
Department of Energy, 1979
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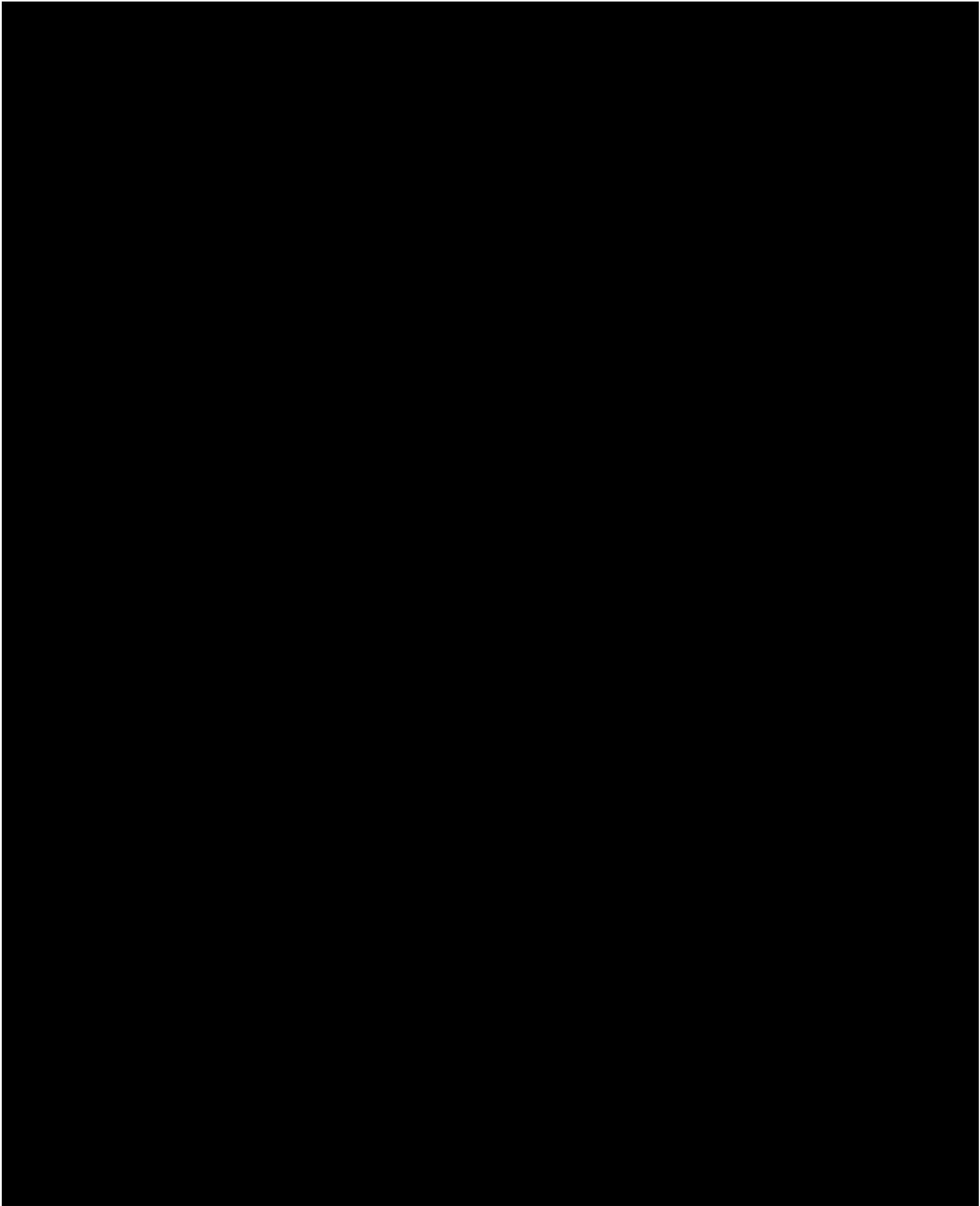
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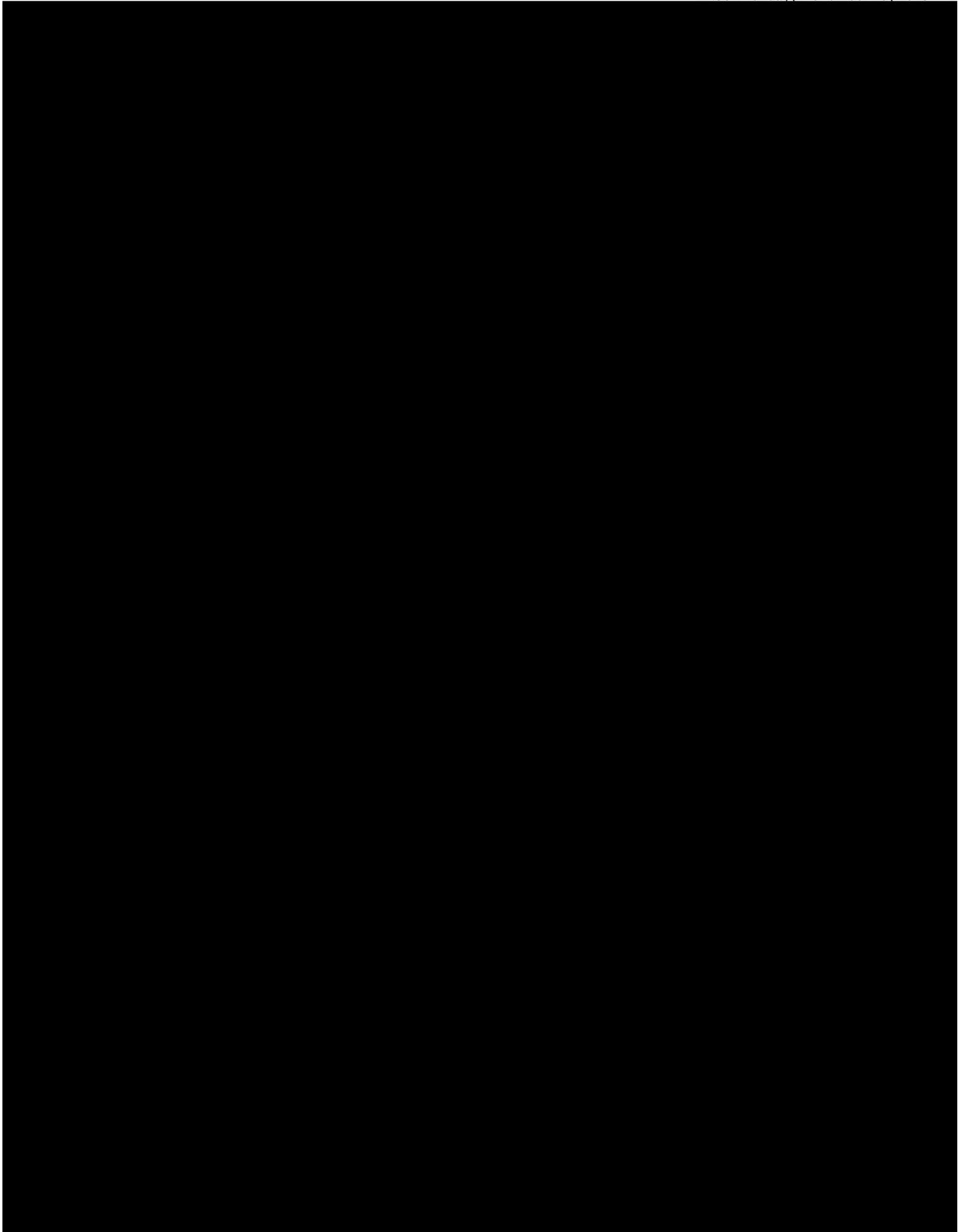
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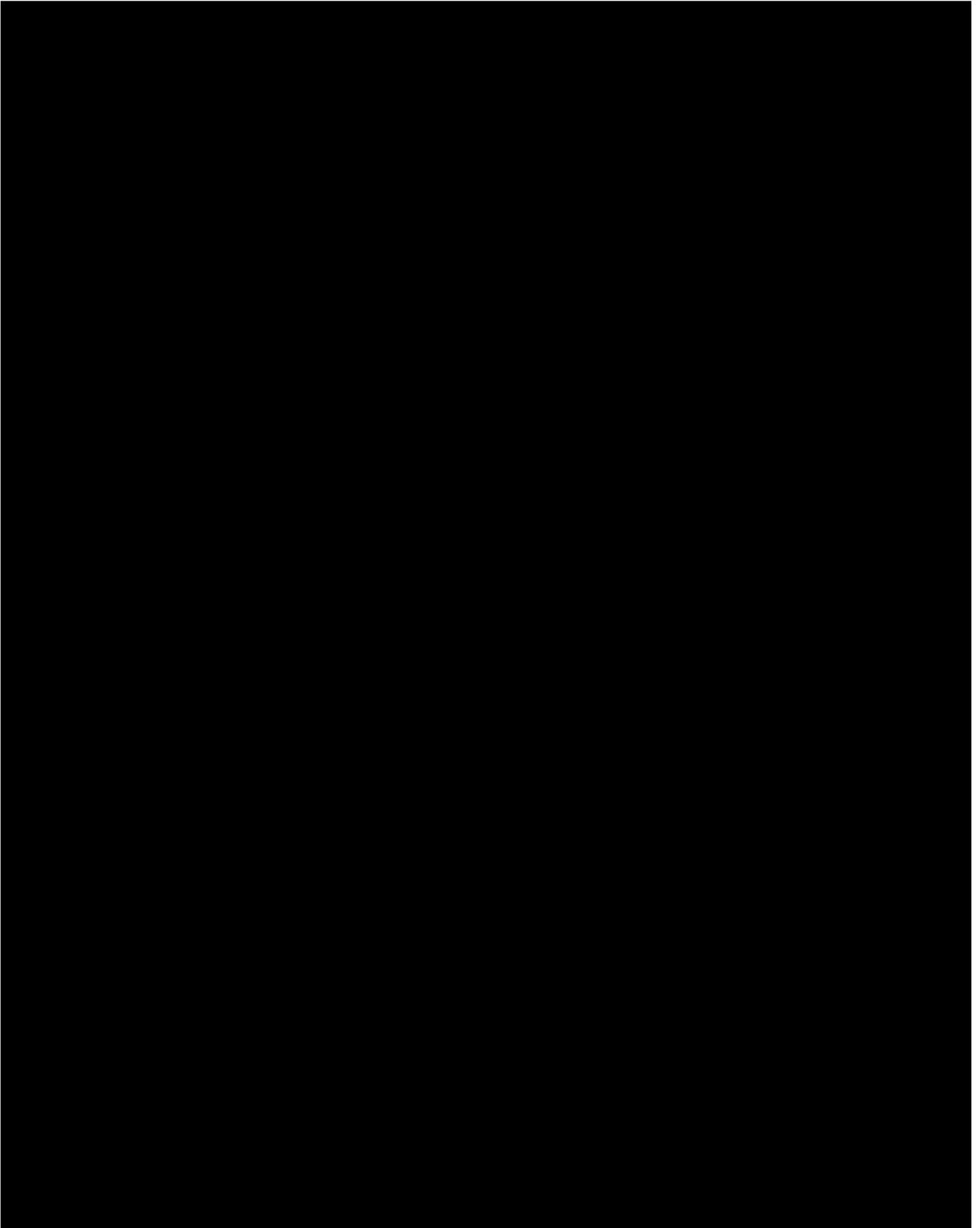
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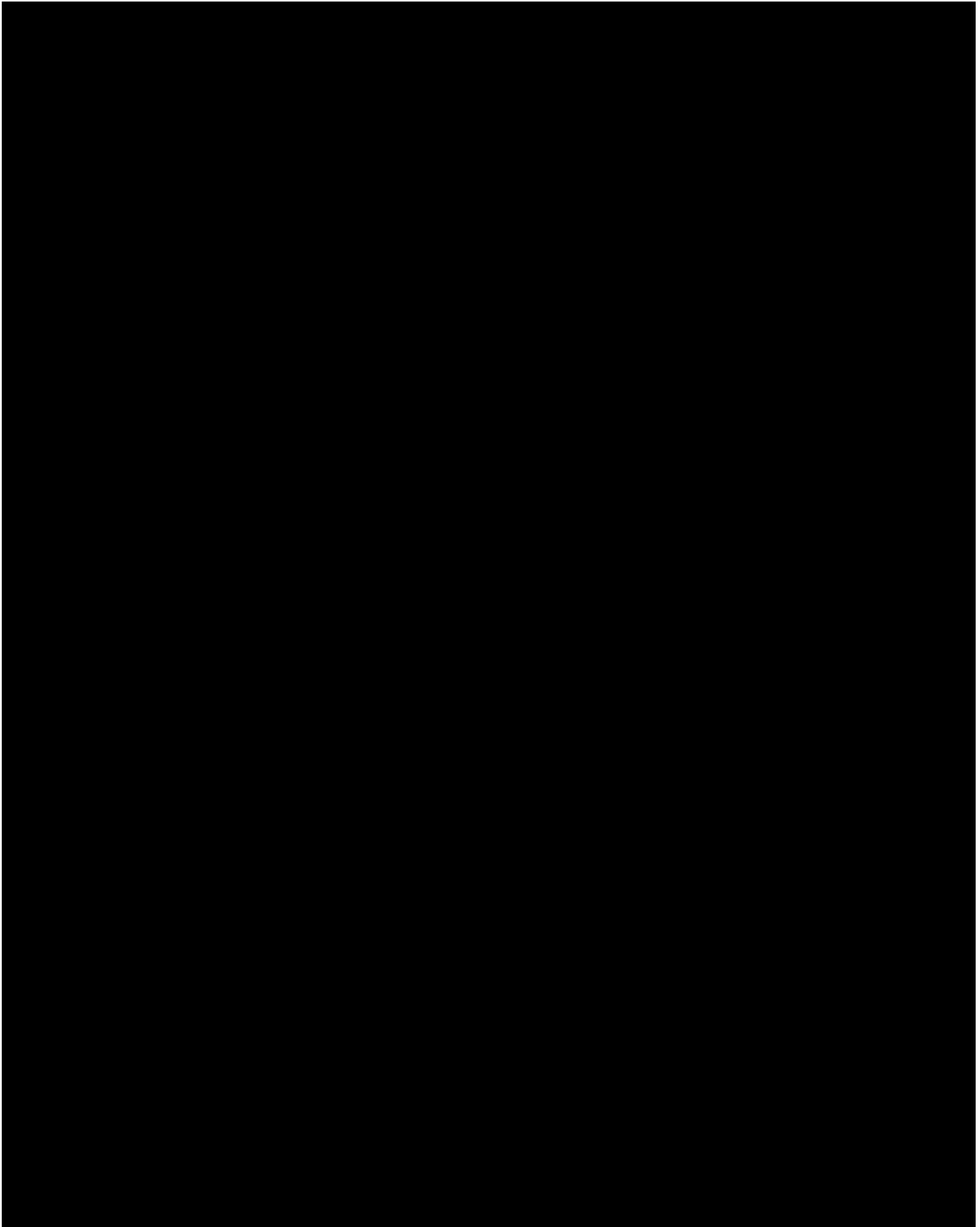
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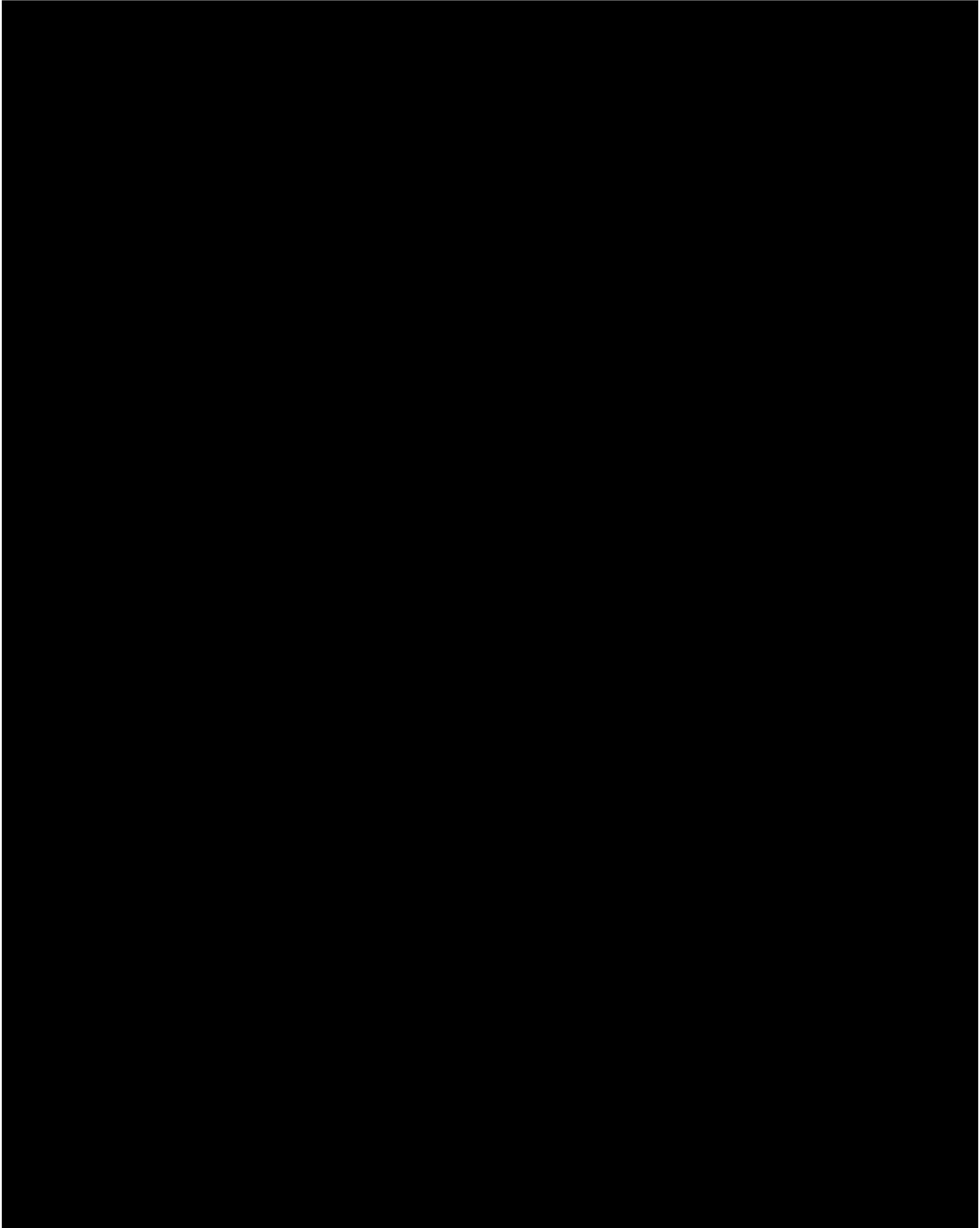
APPENDIX B

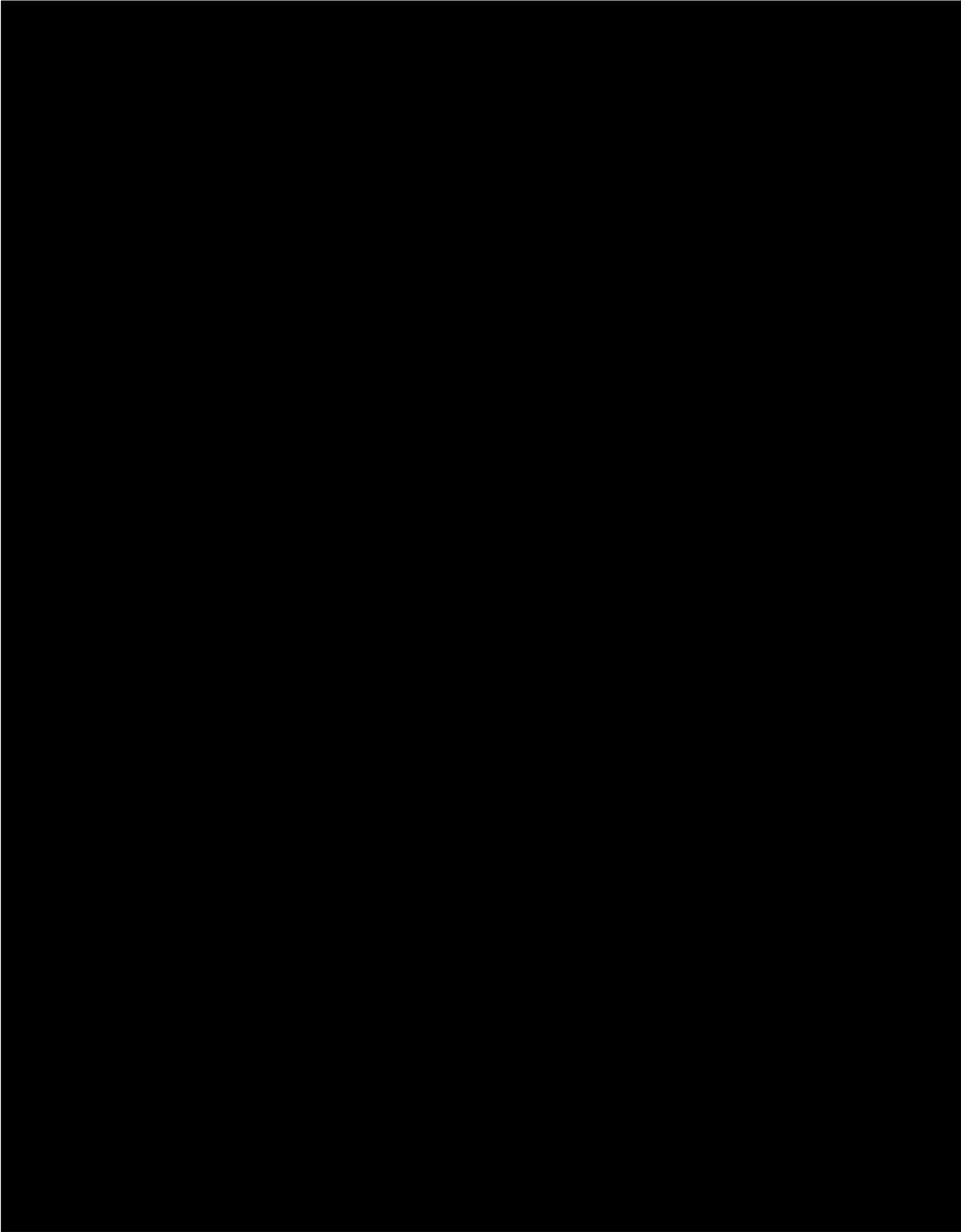


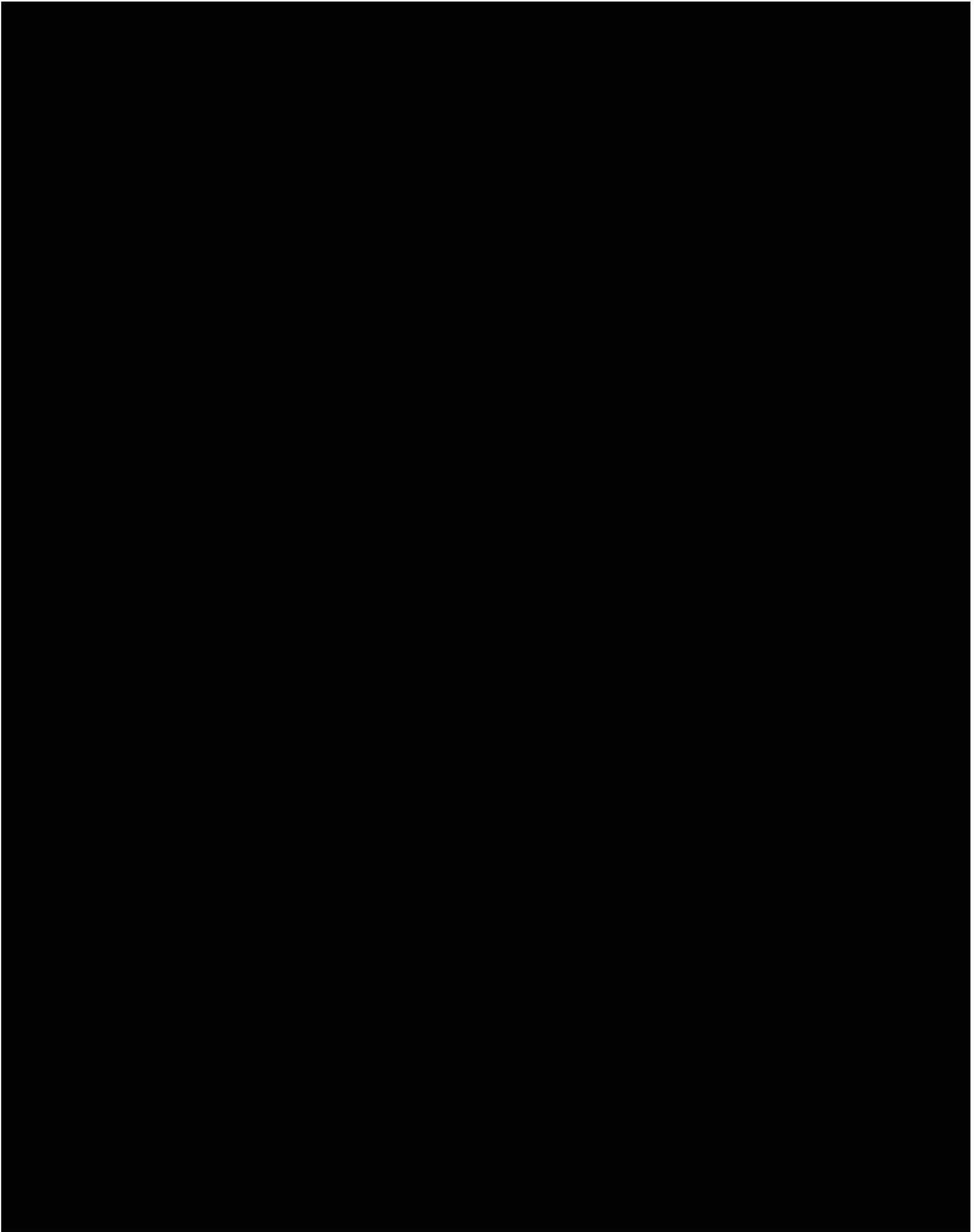


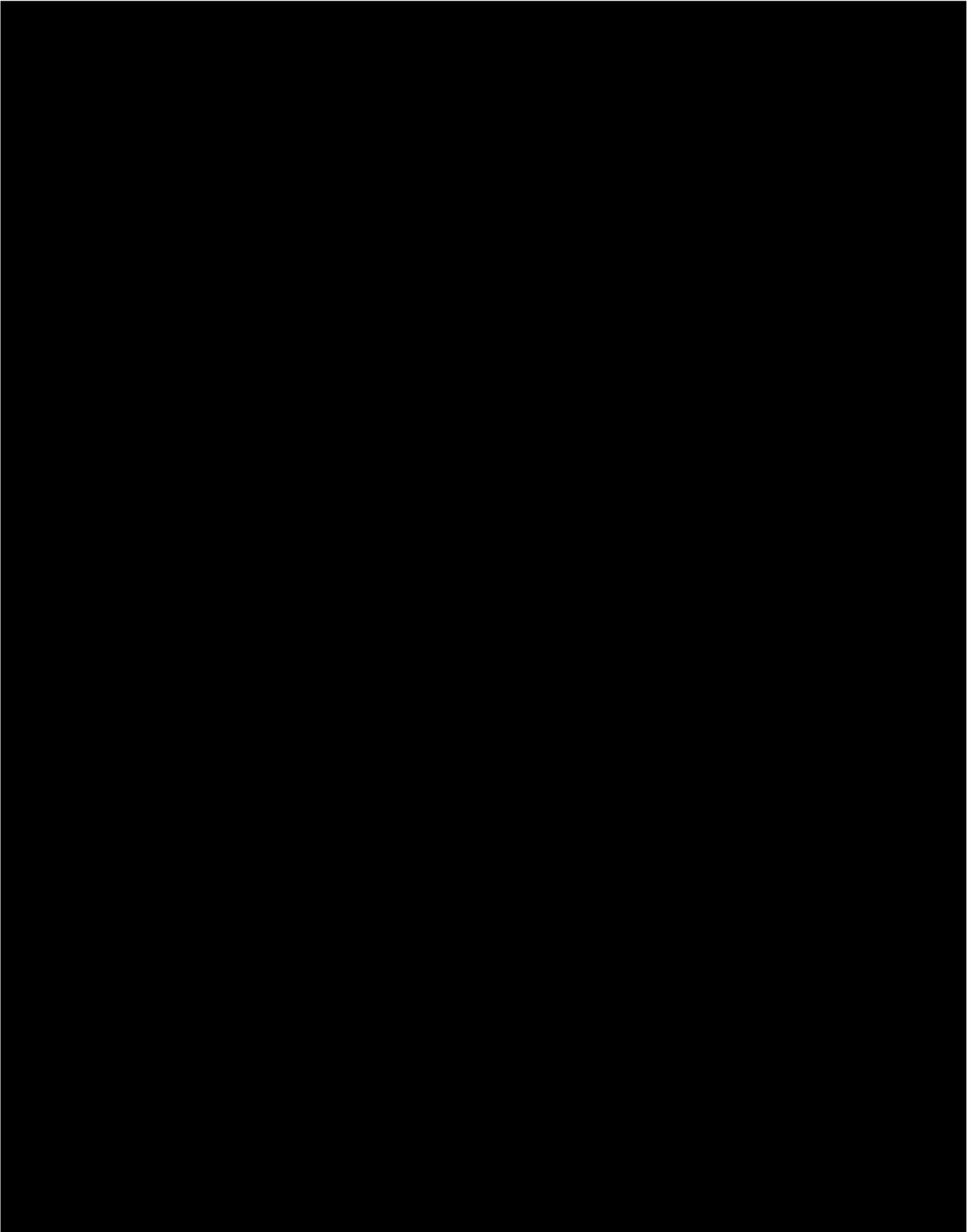


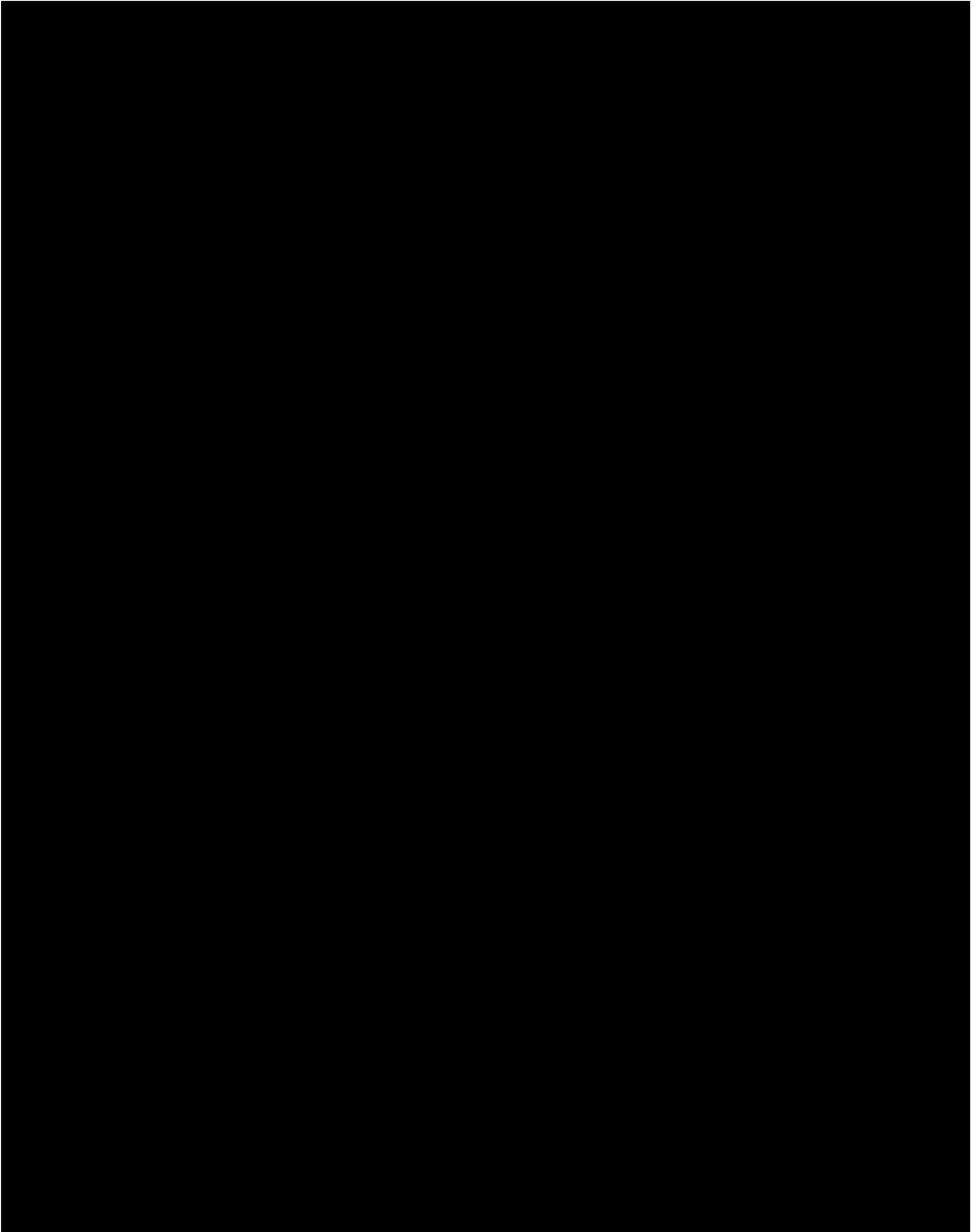


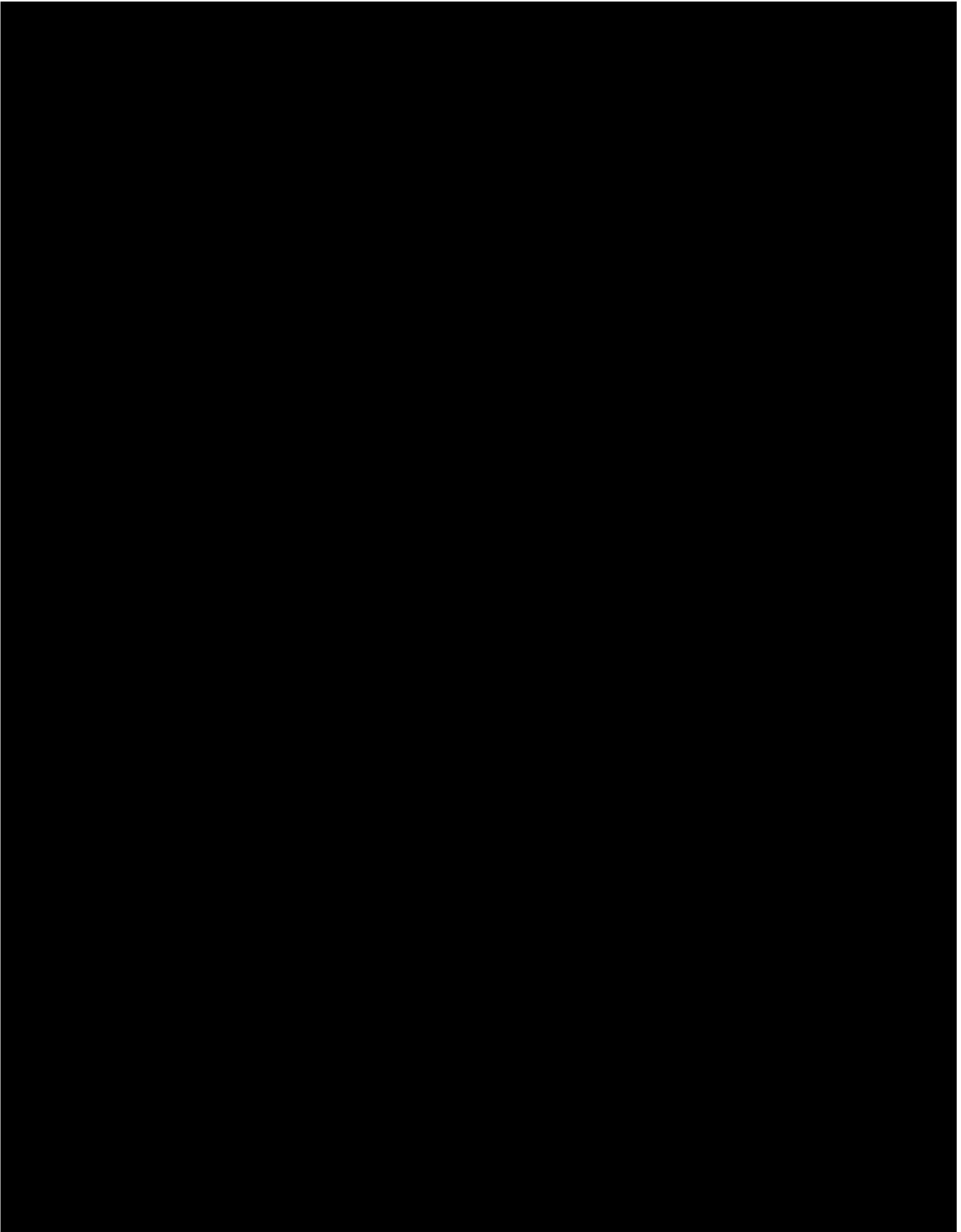


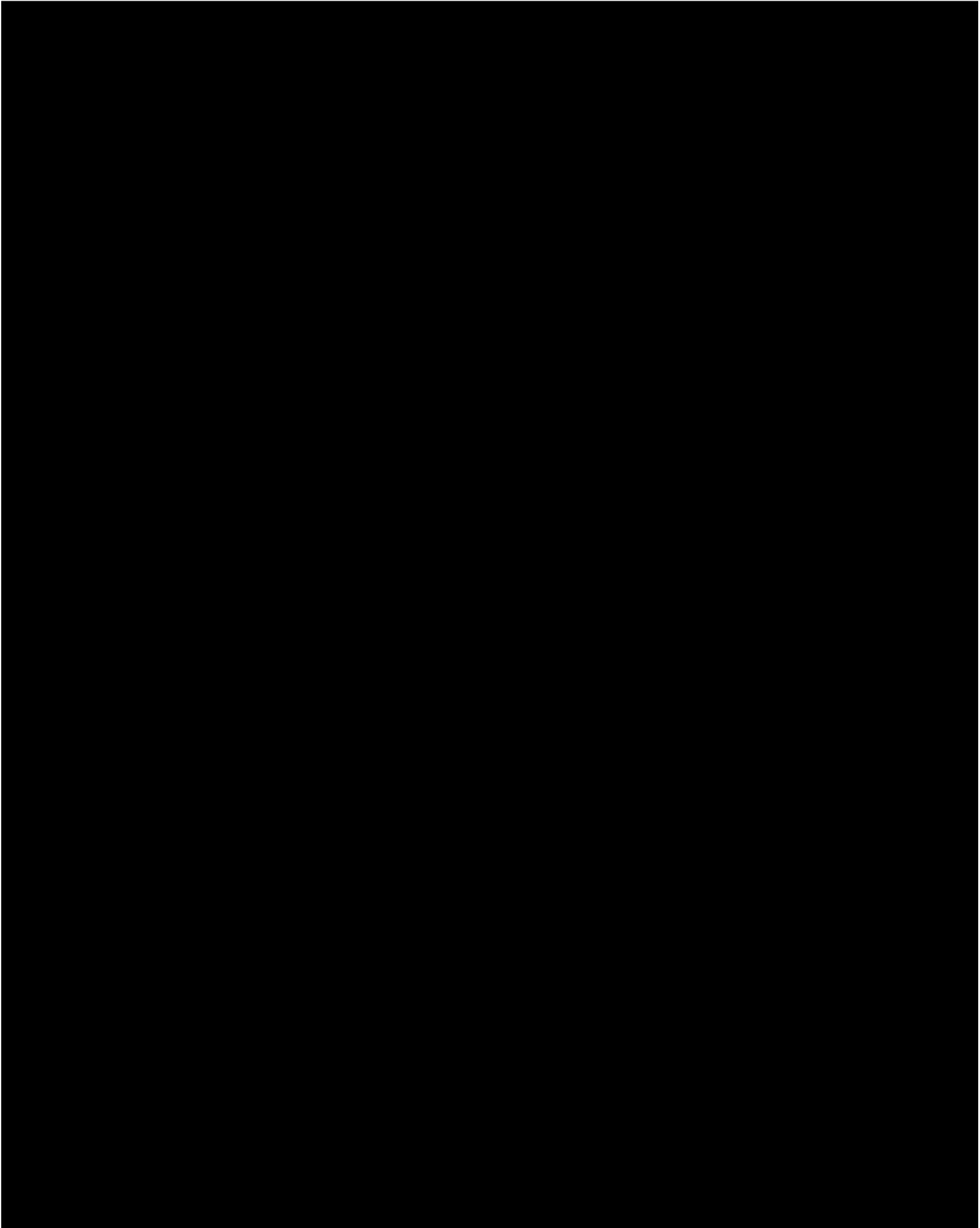


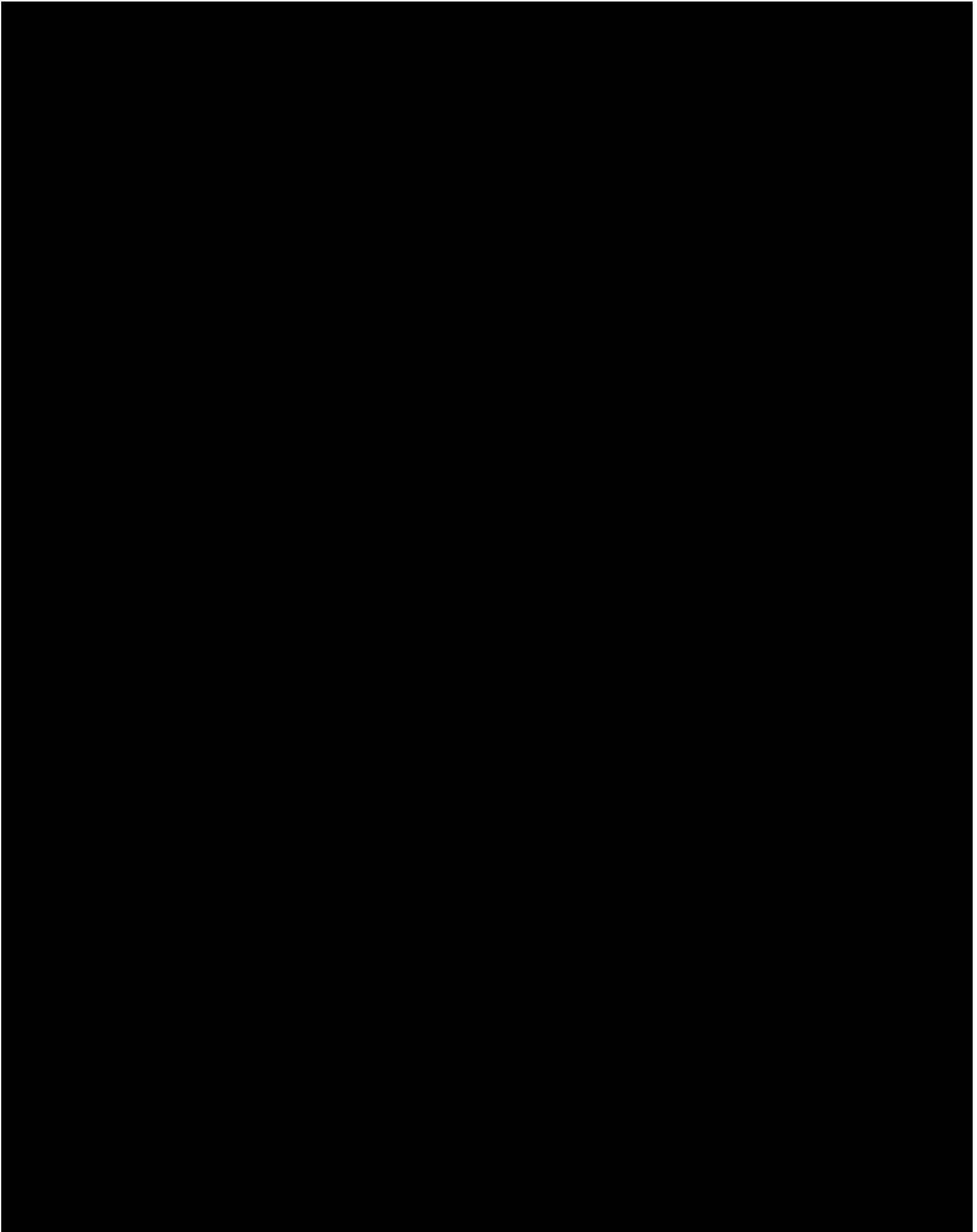


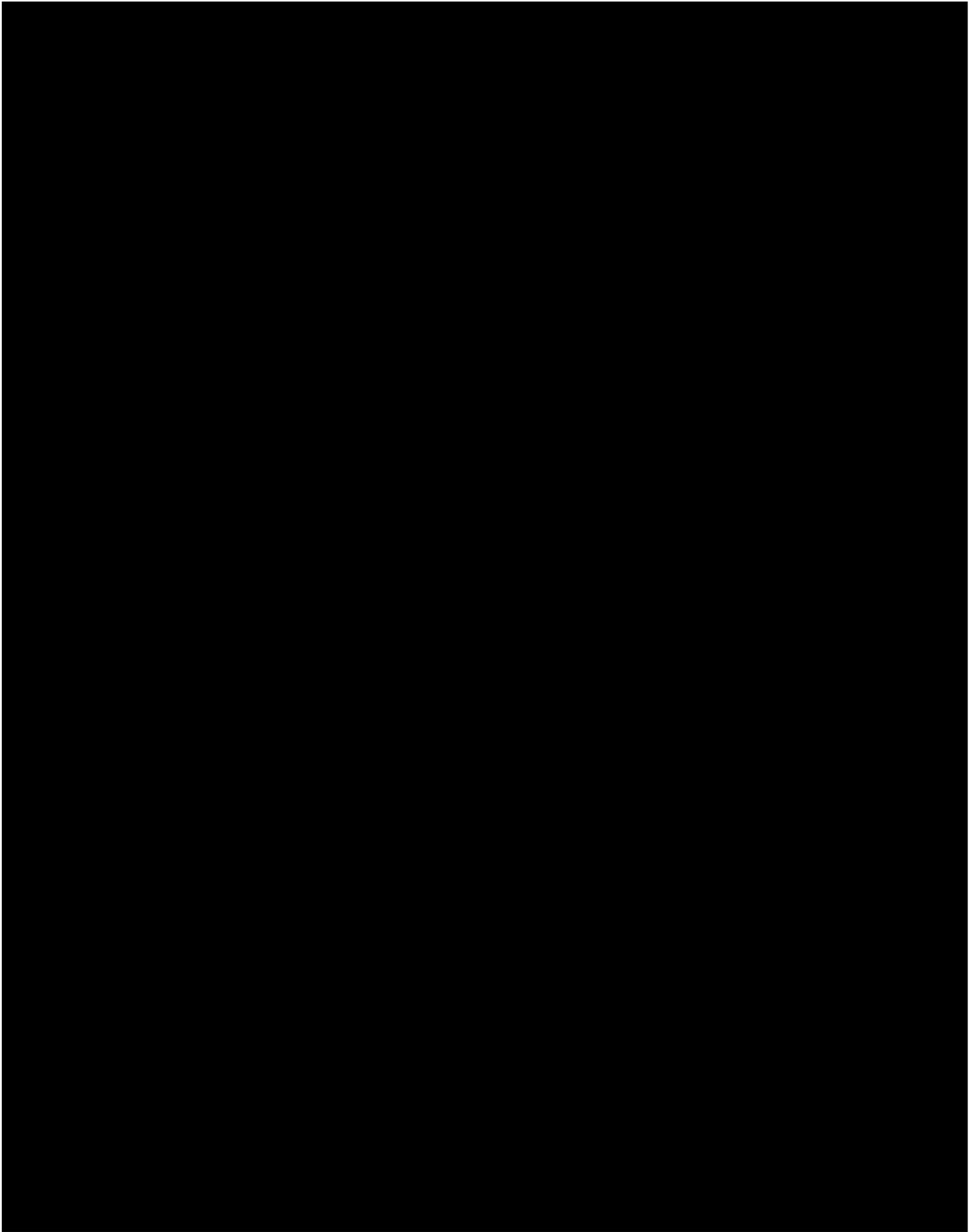


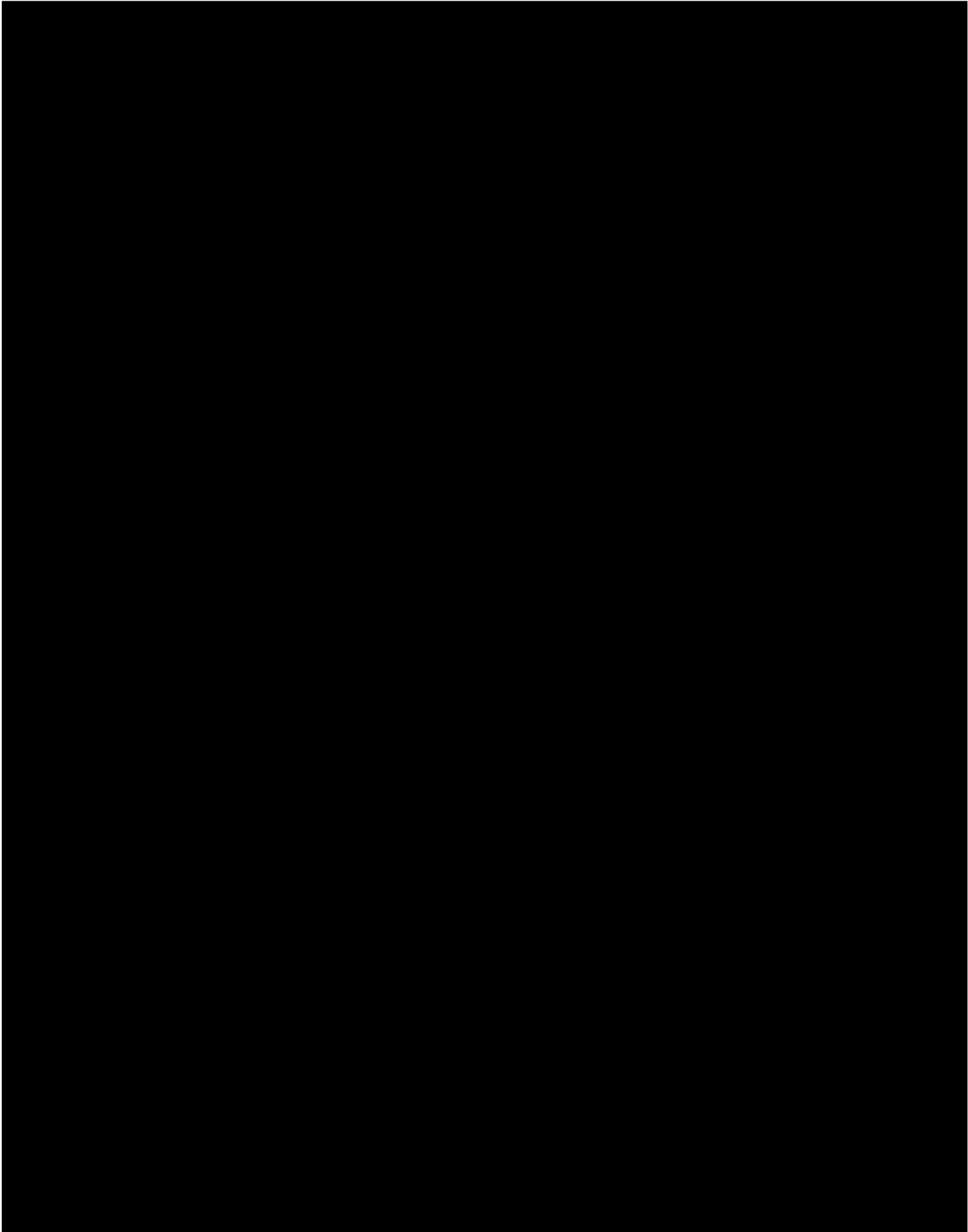


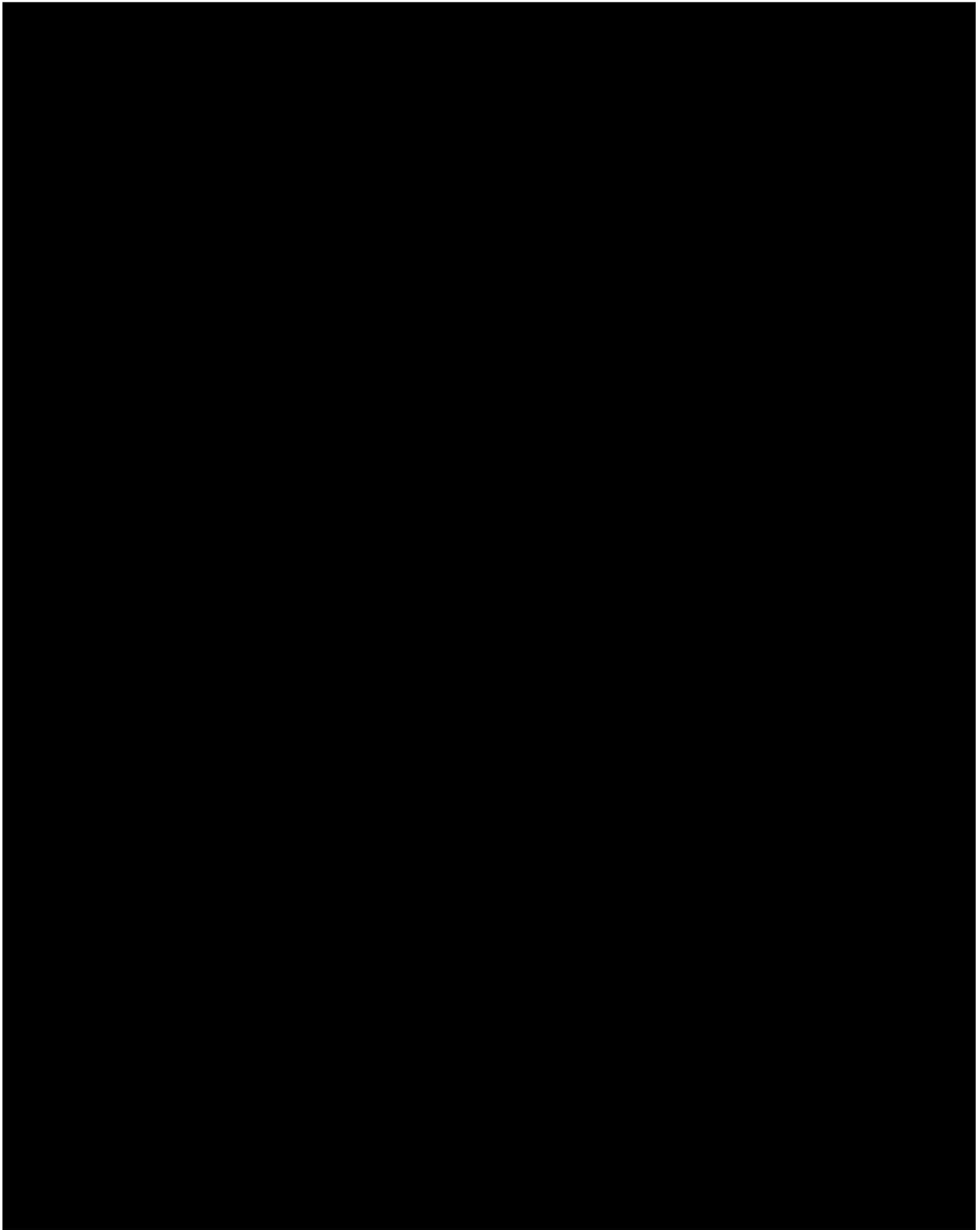


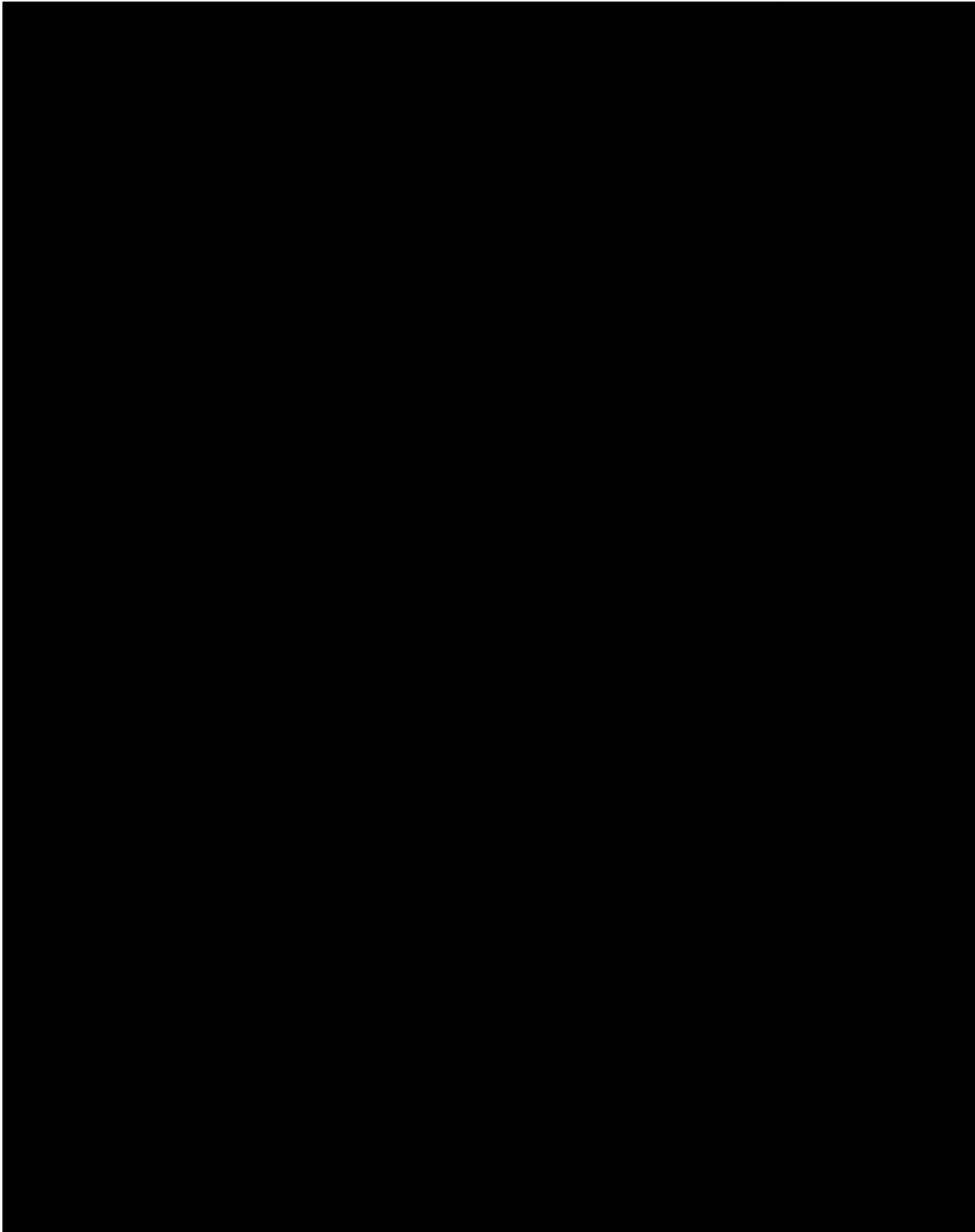


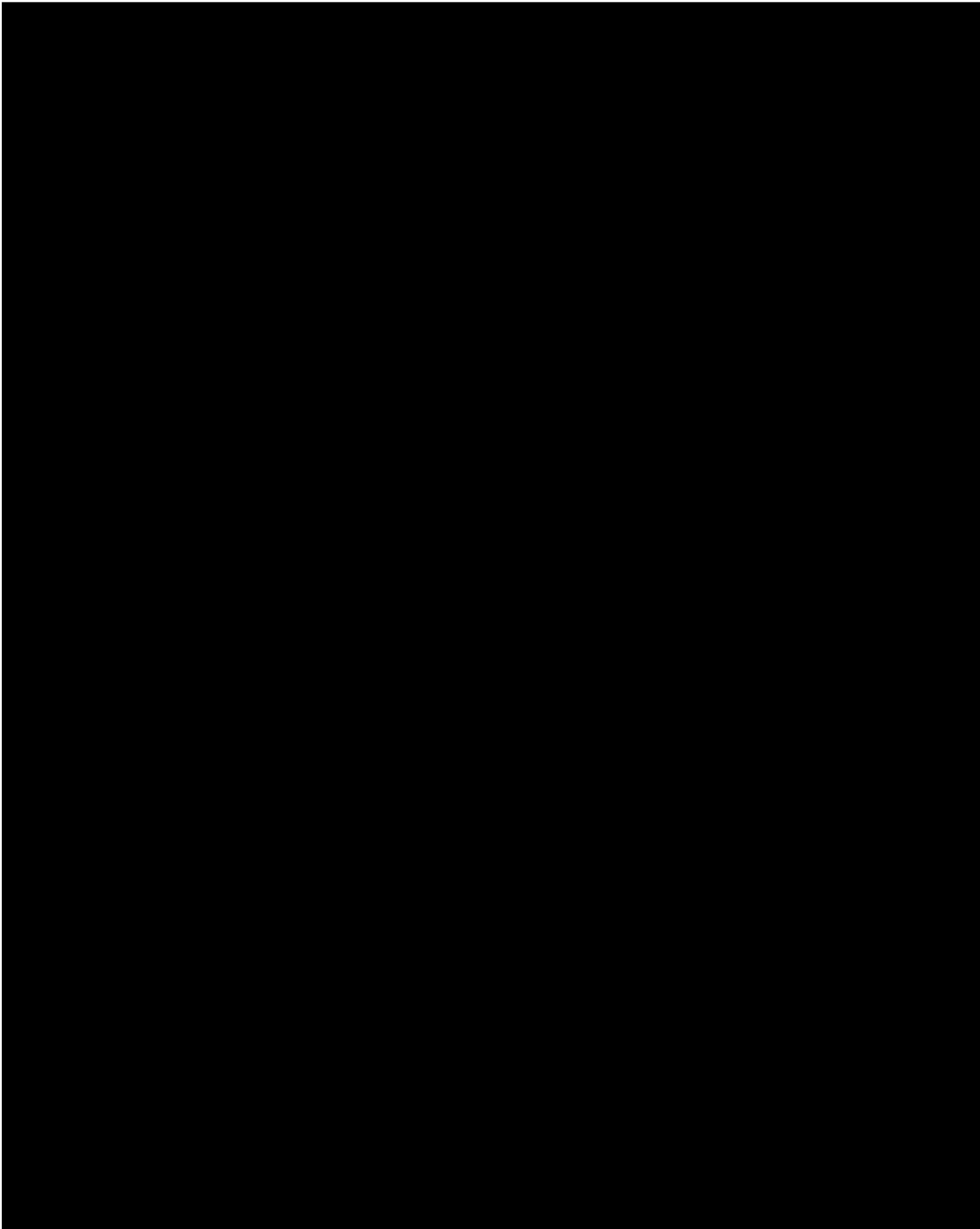


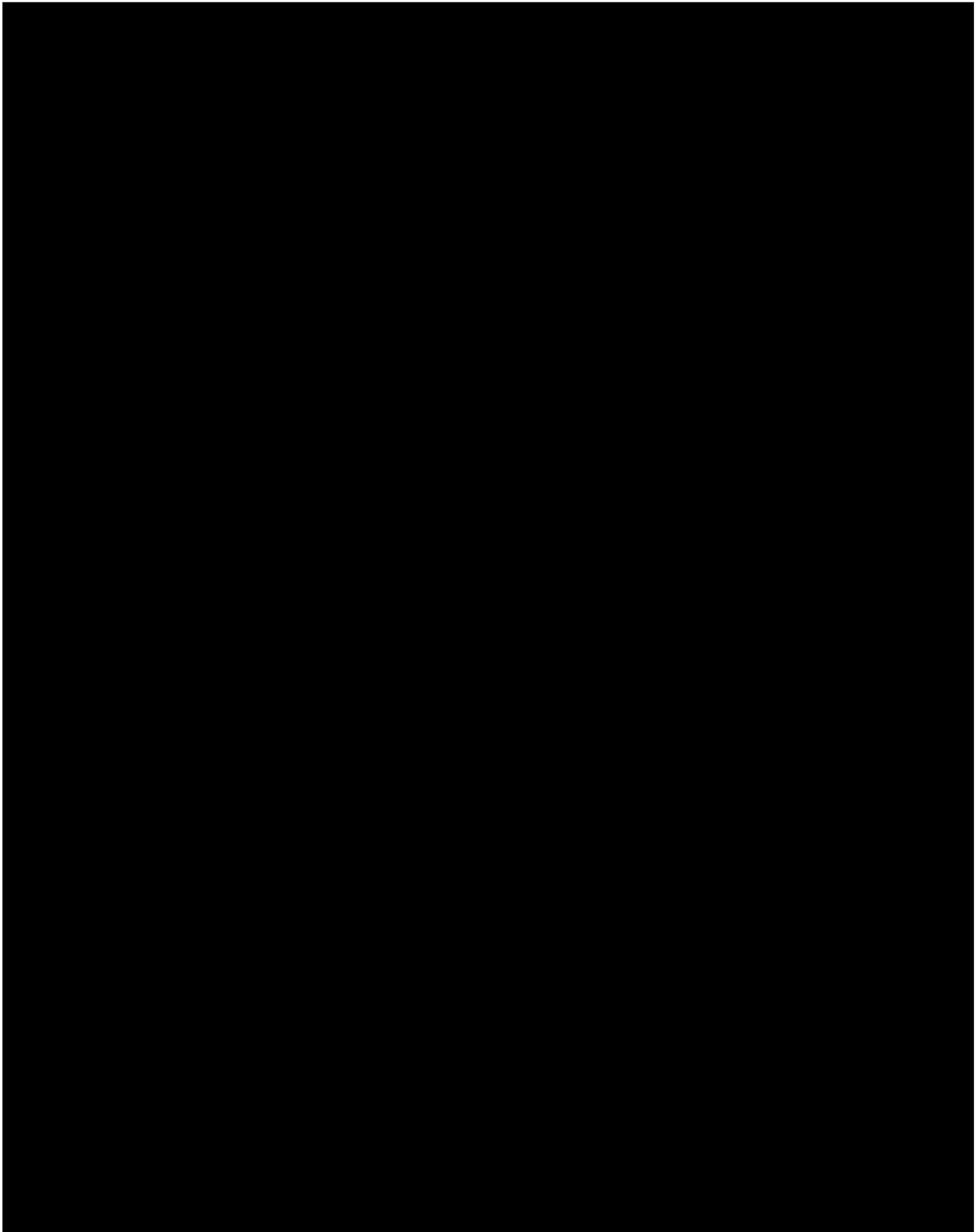


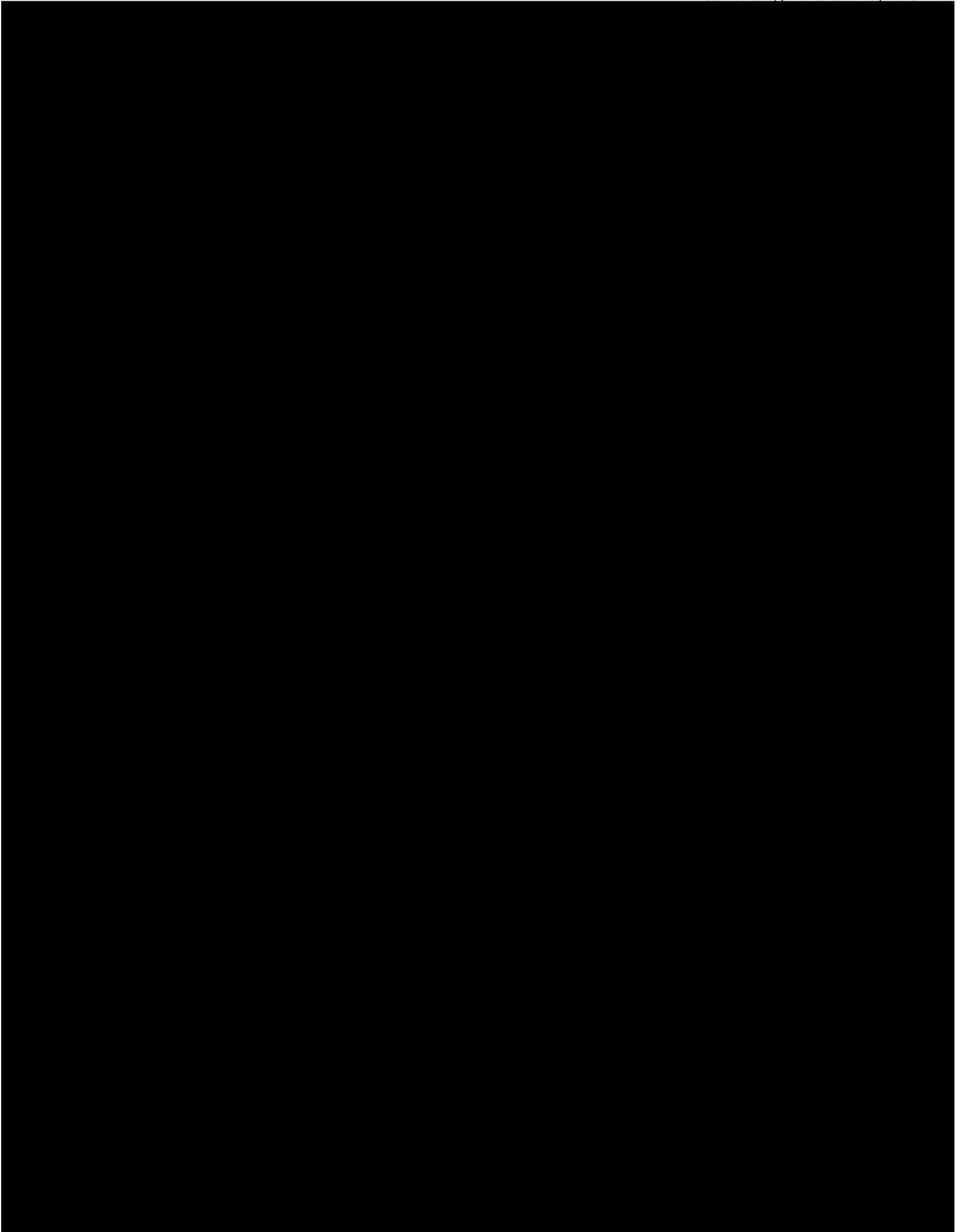


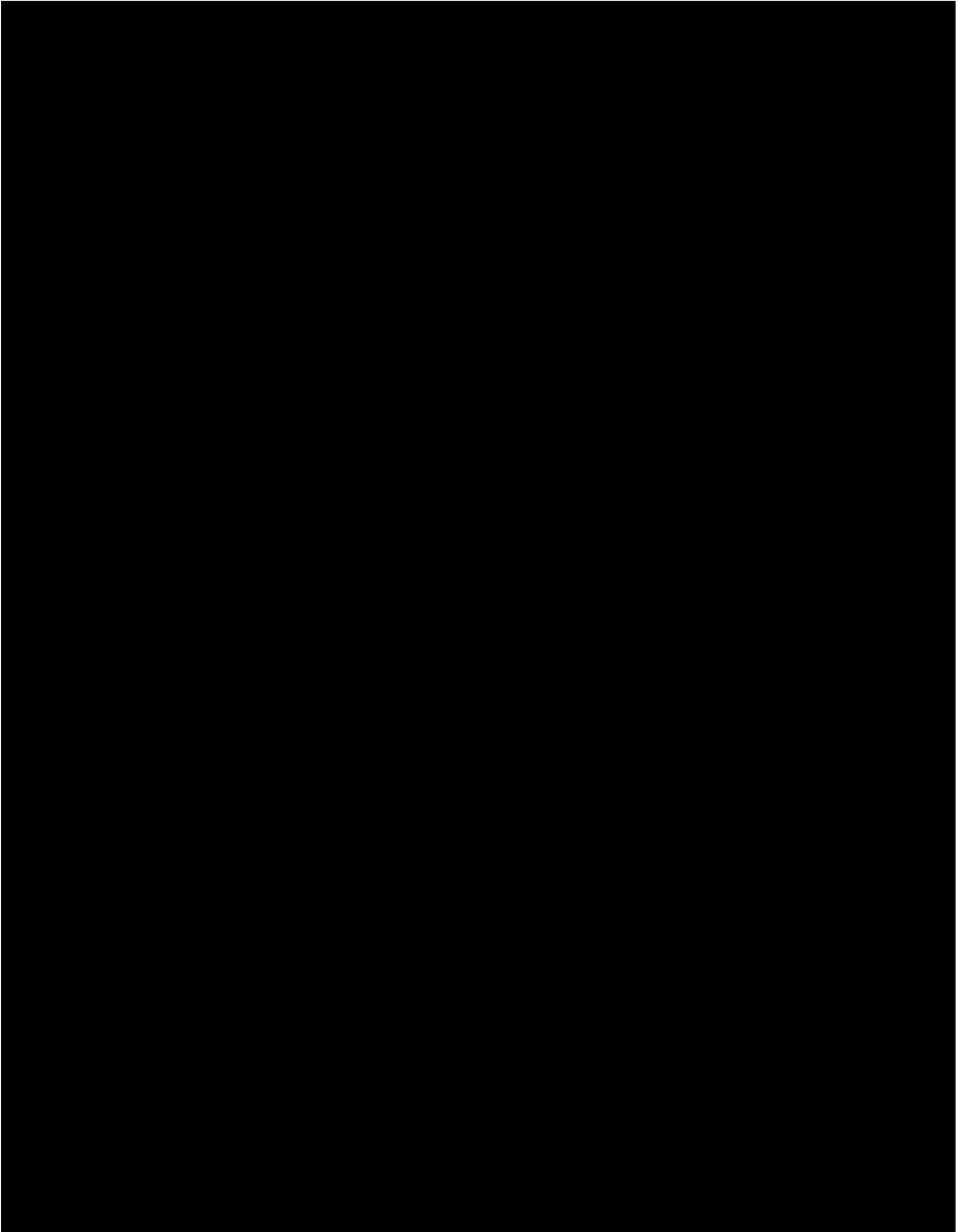


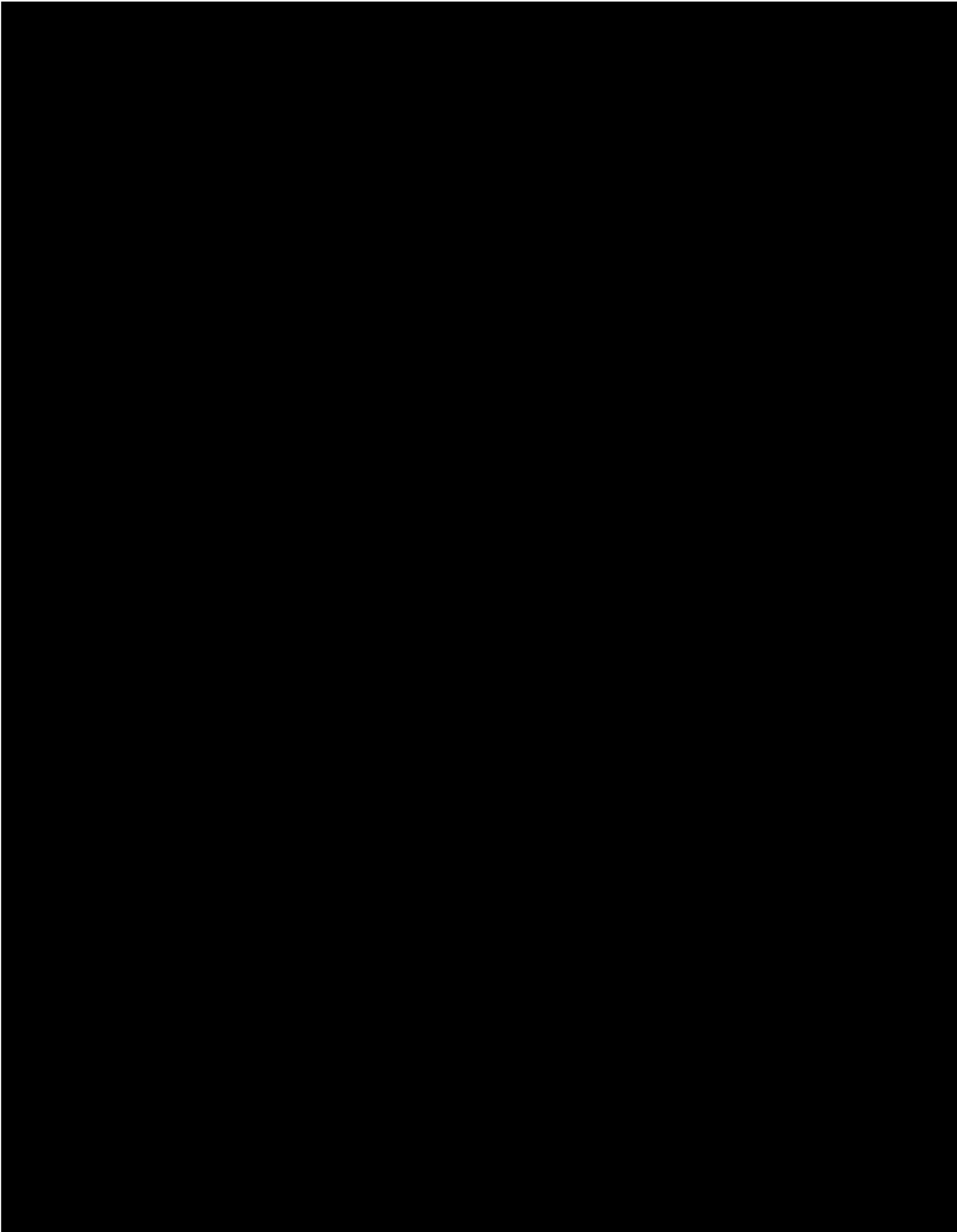


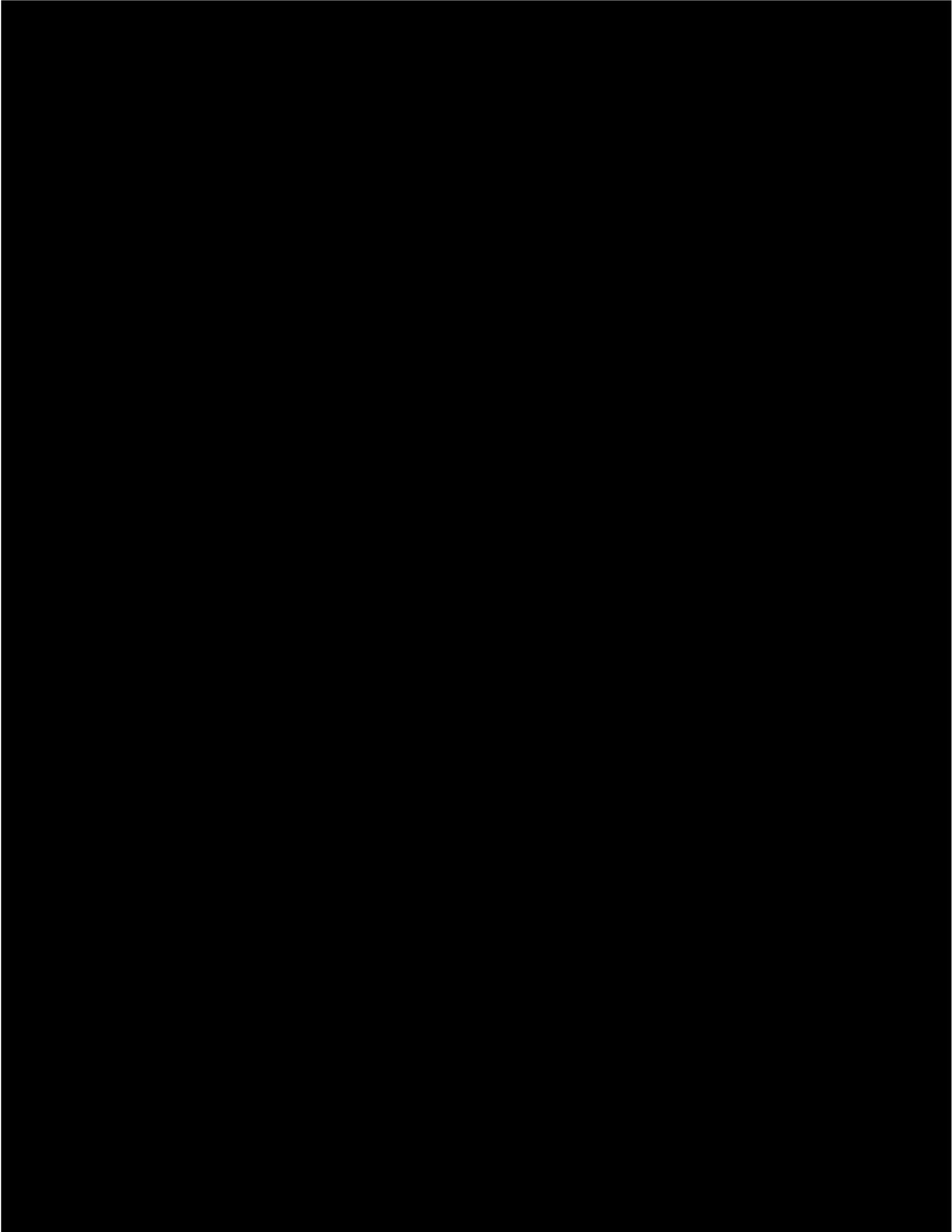


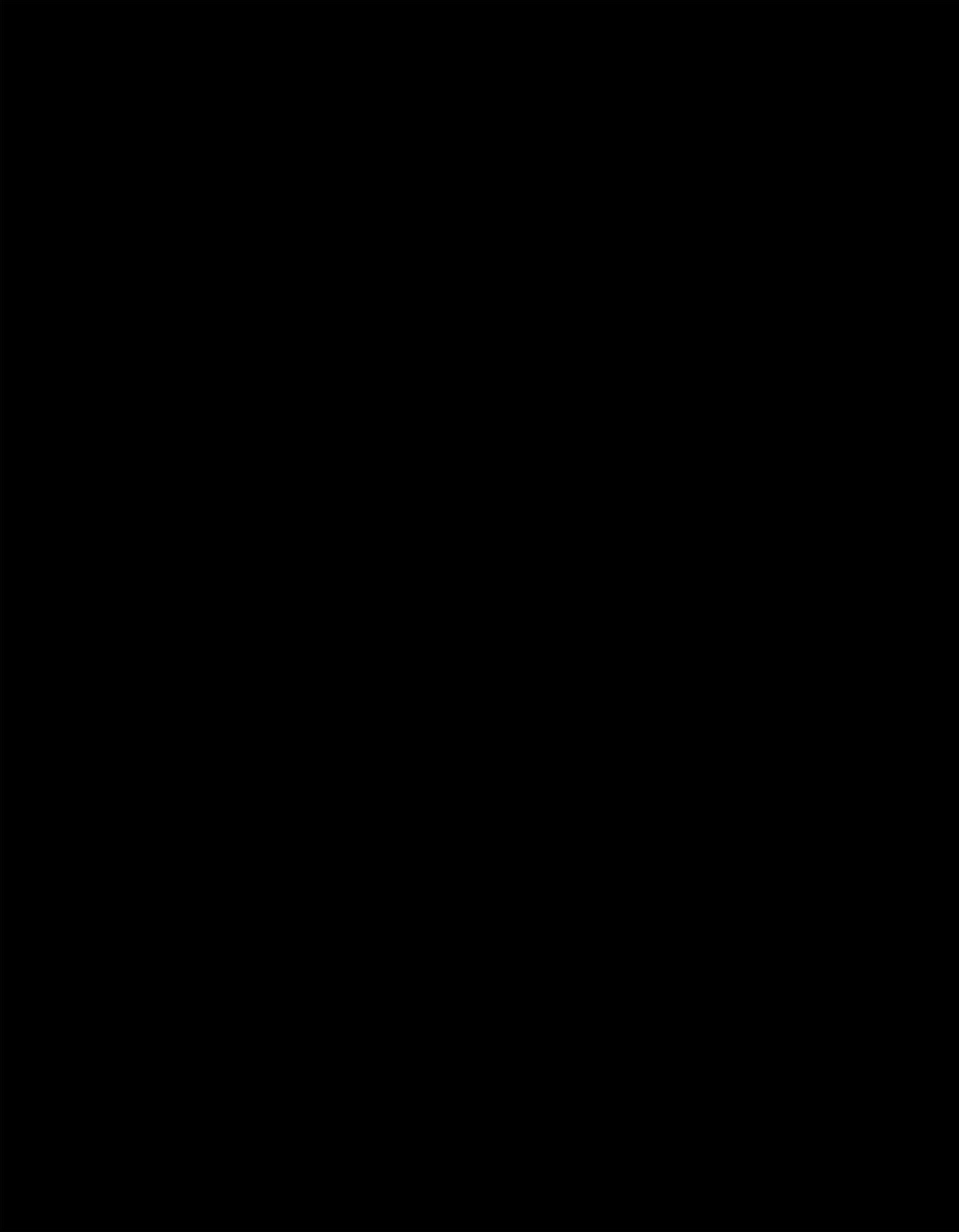


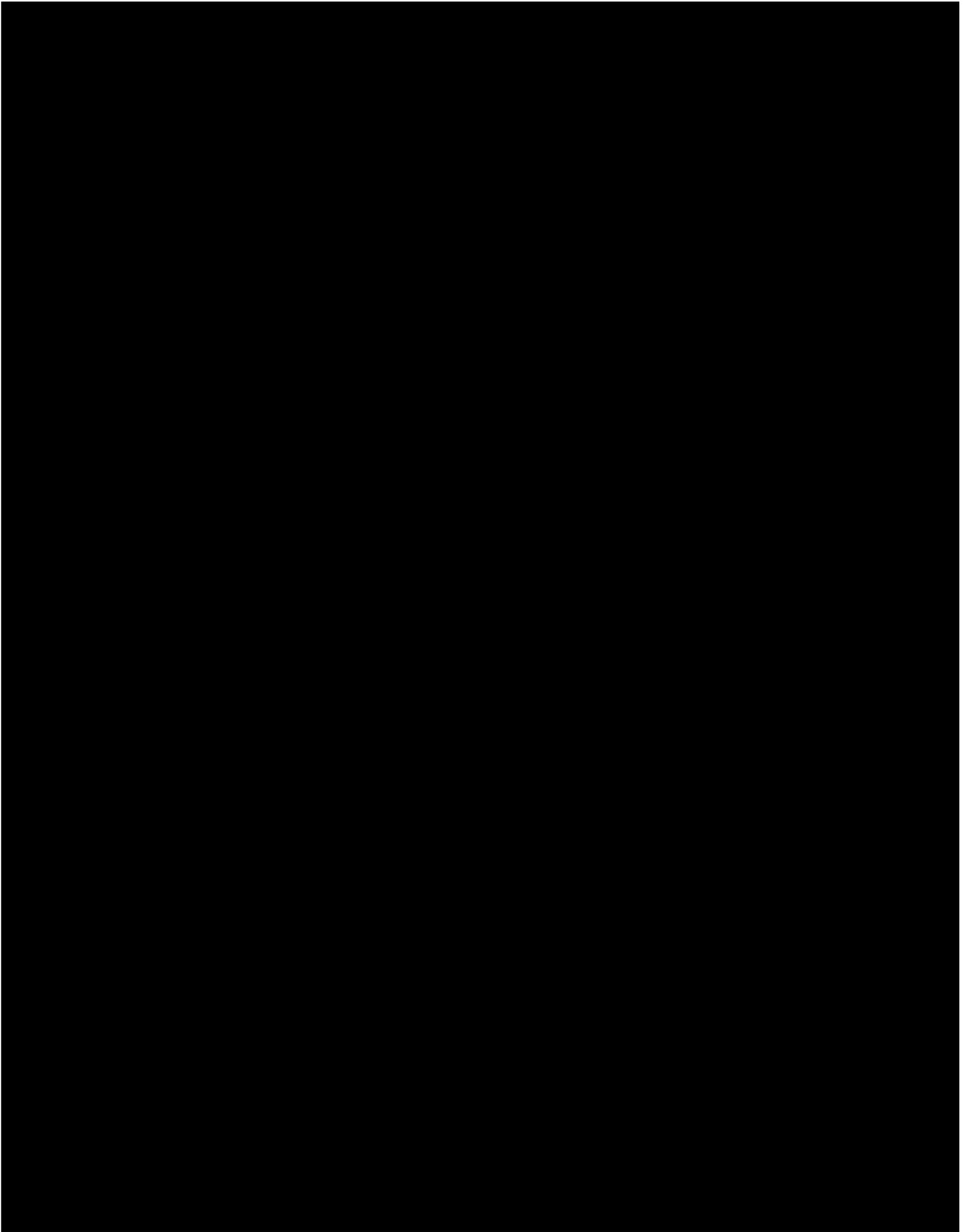


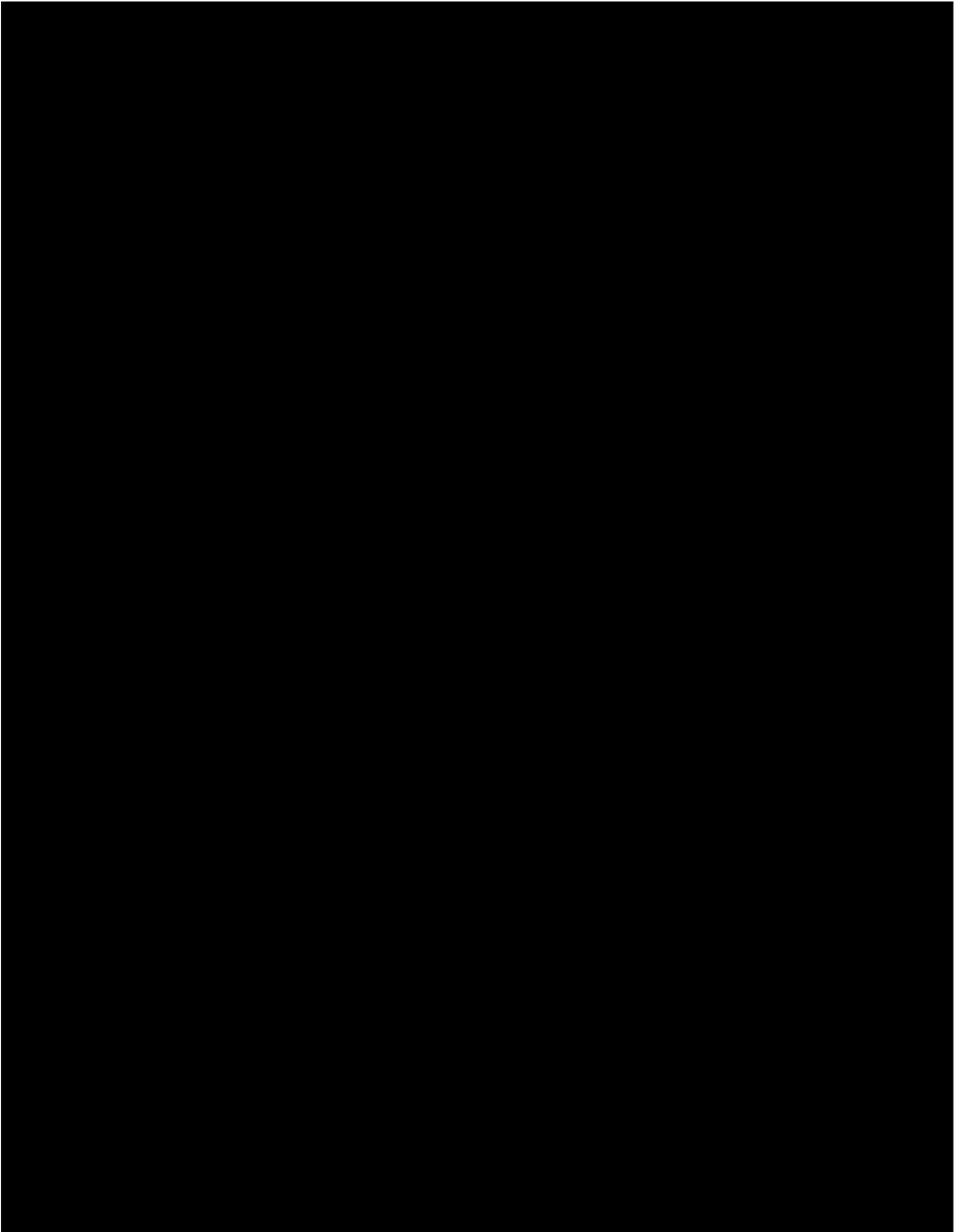


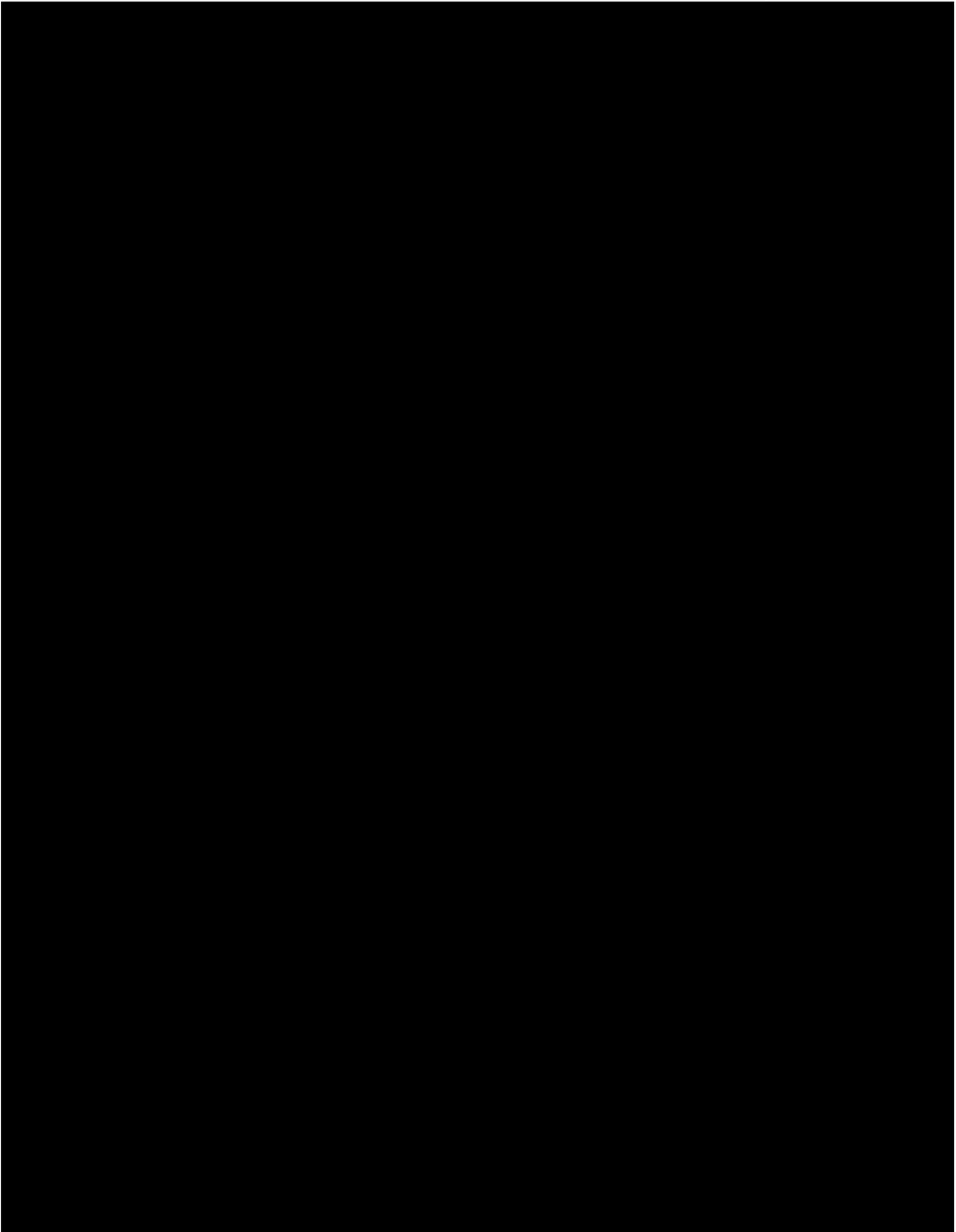


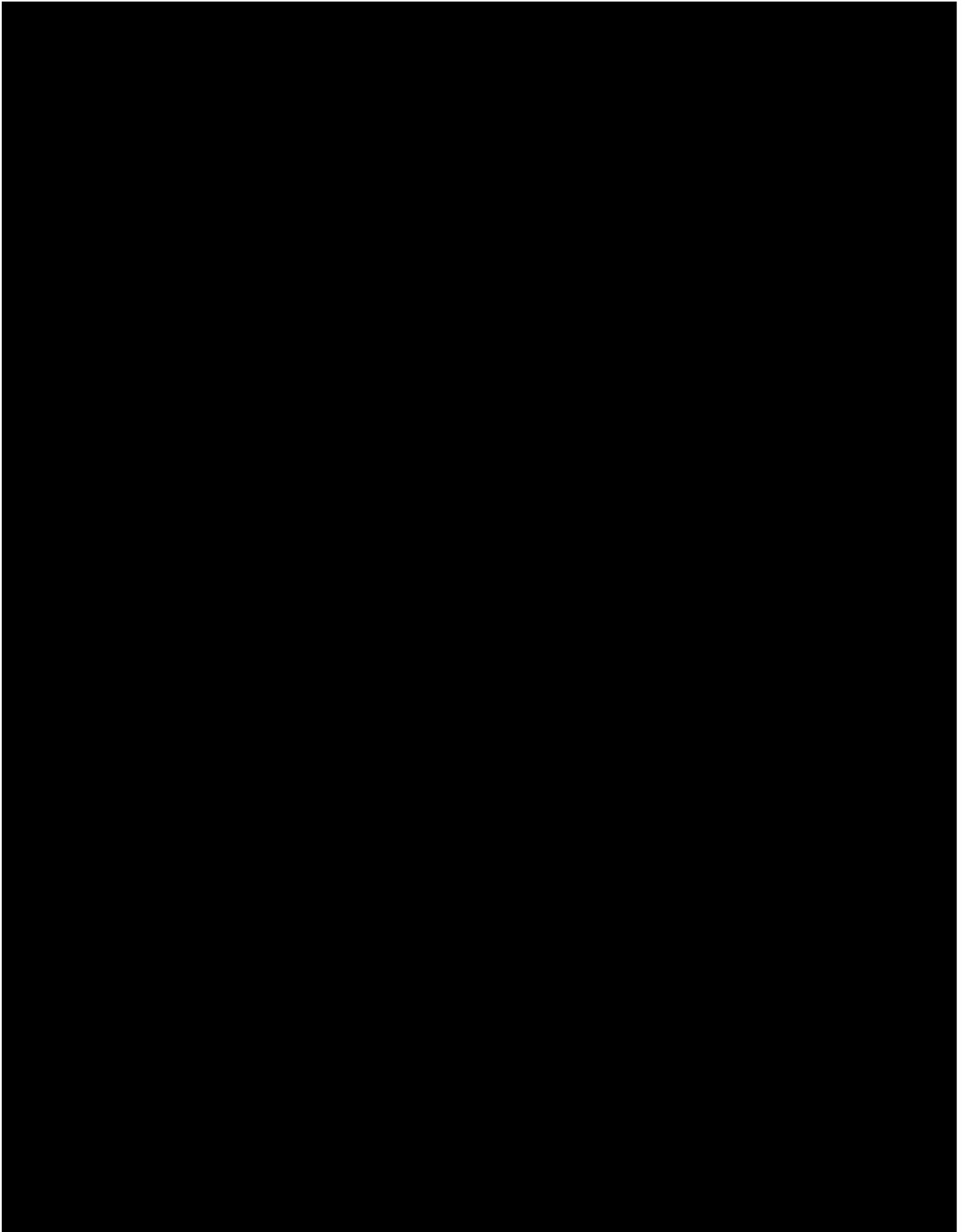


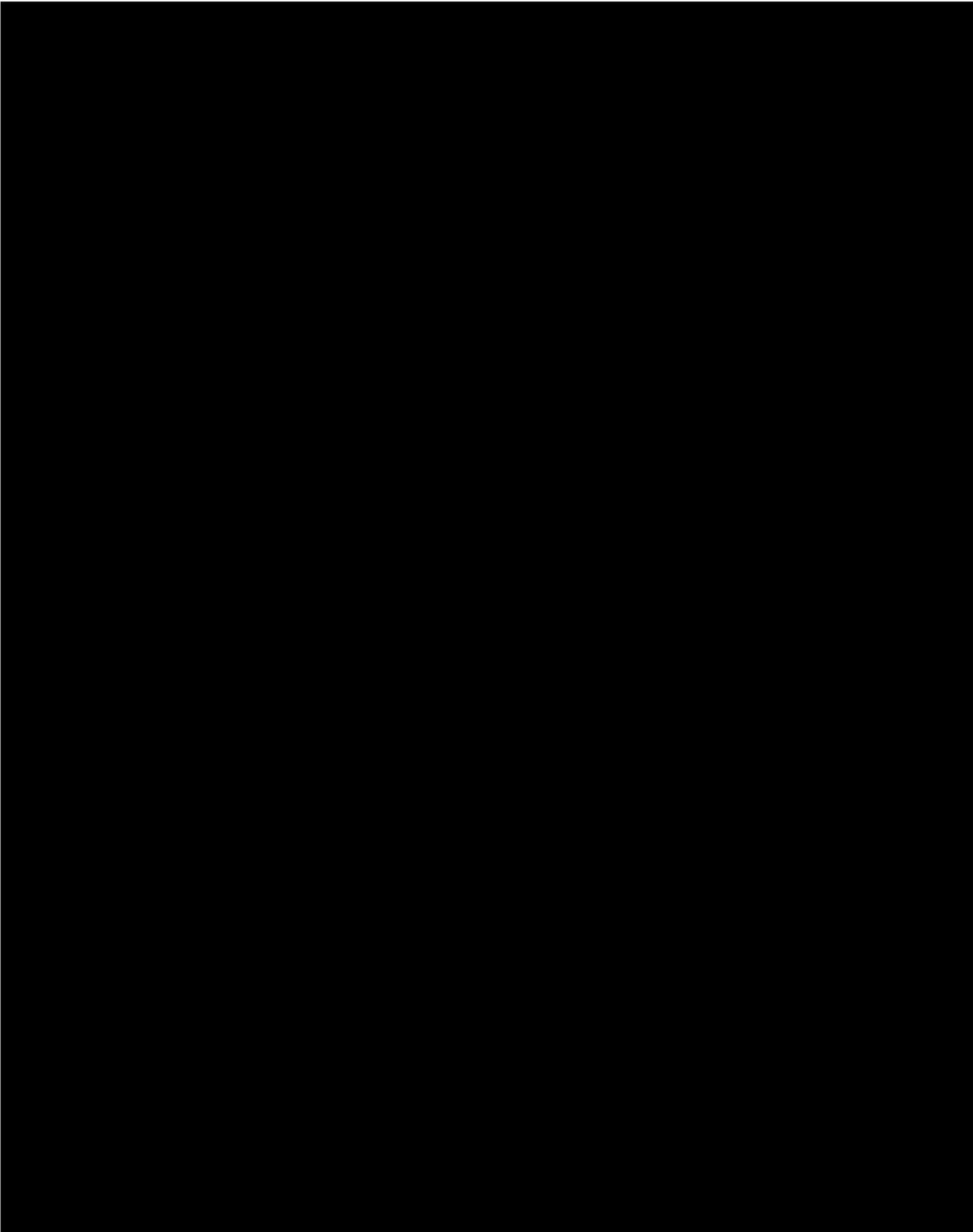


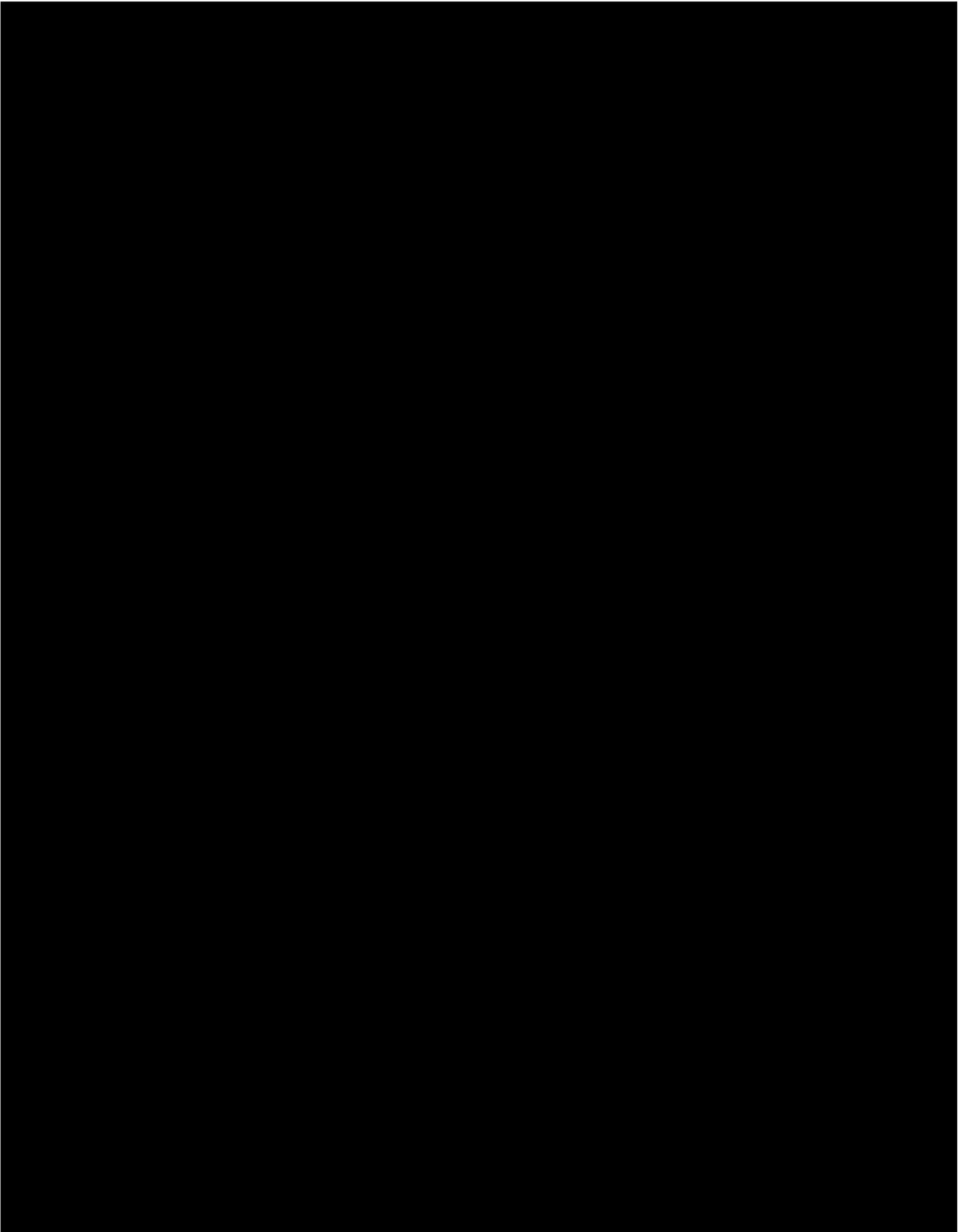


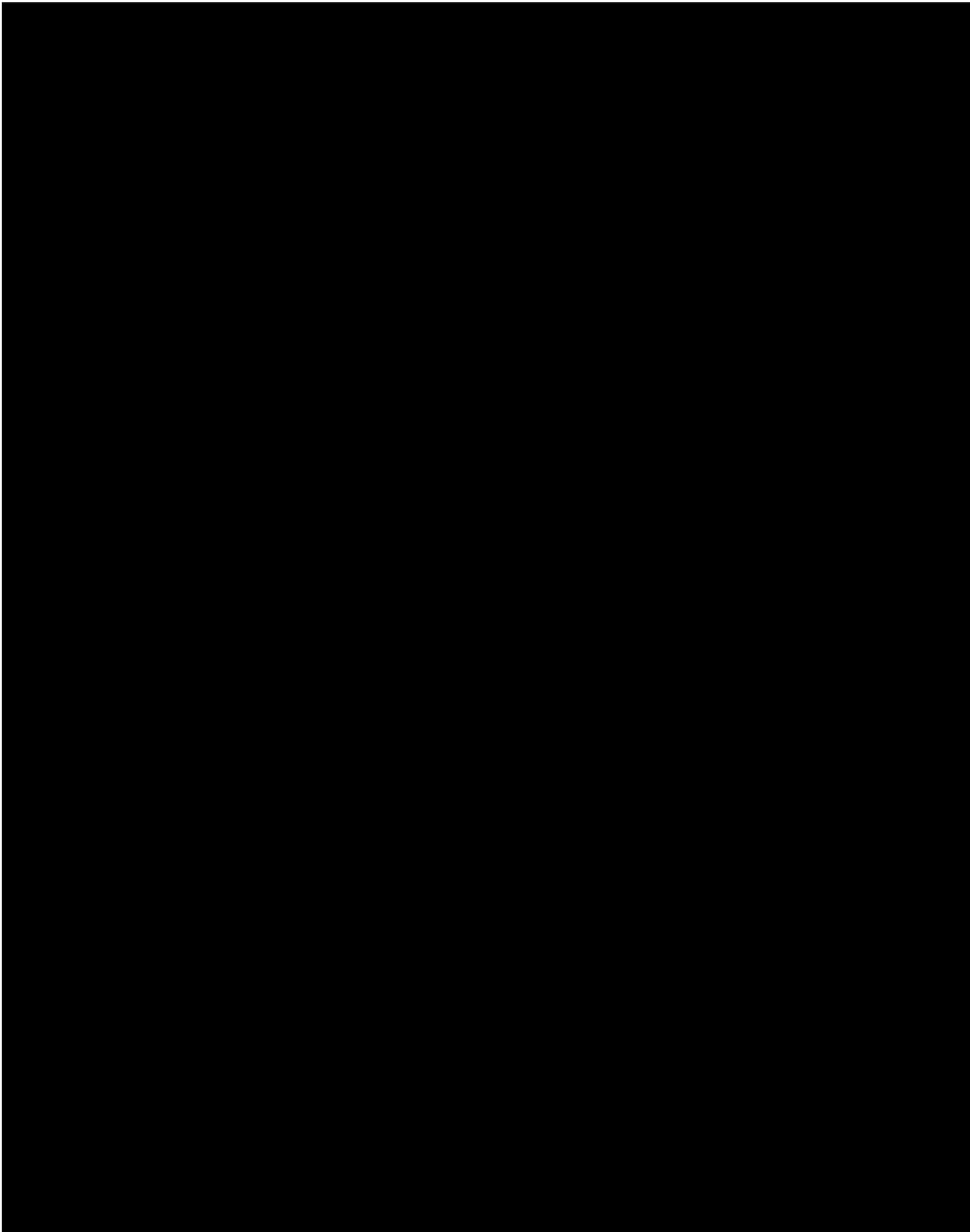


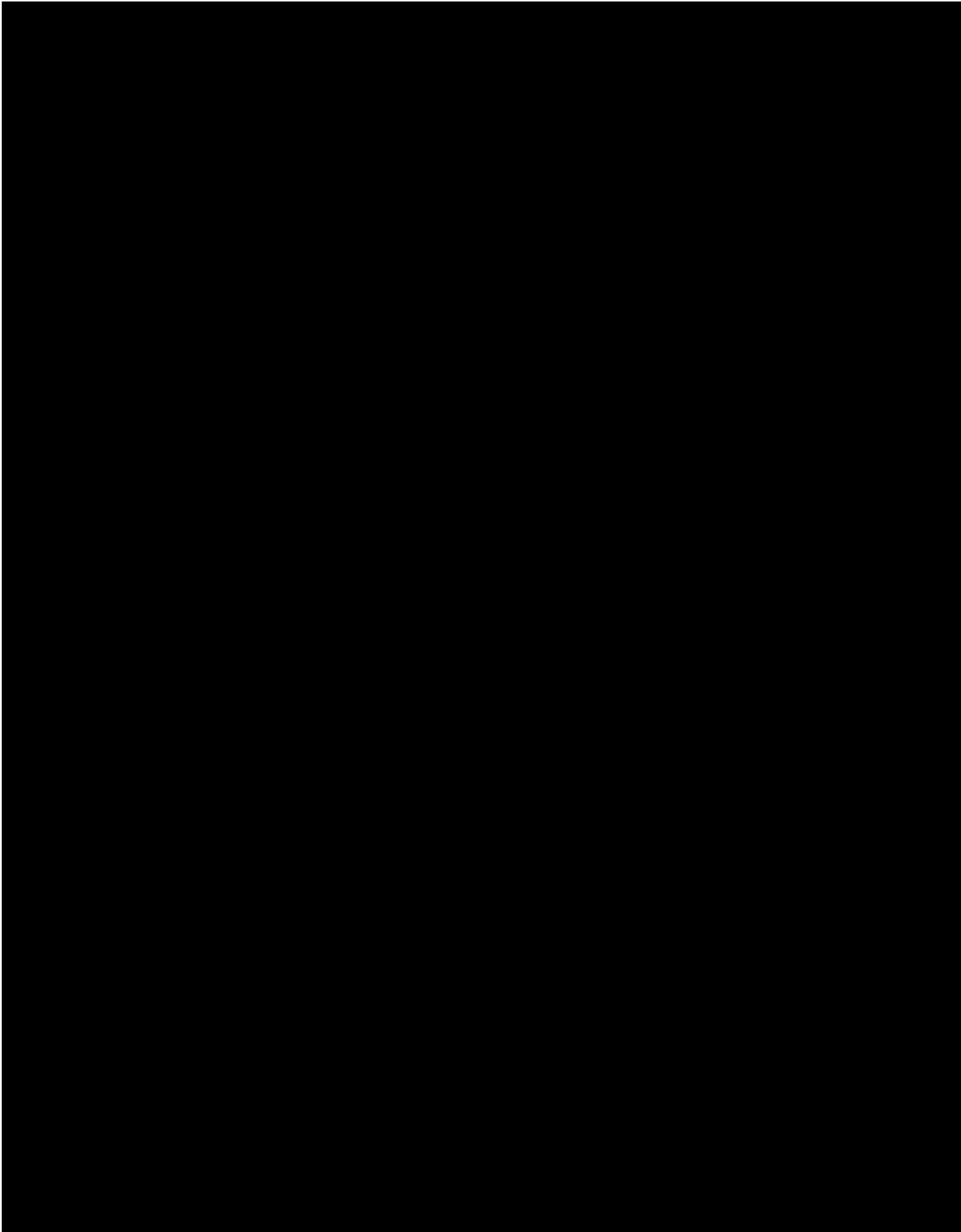


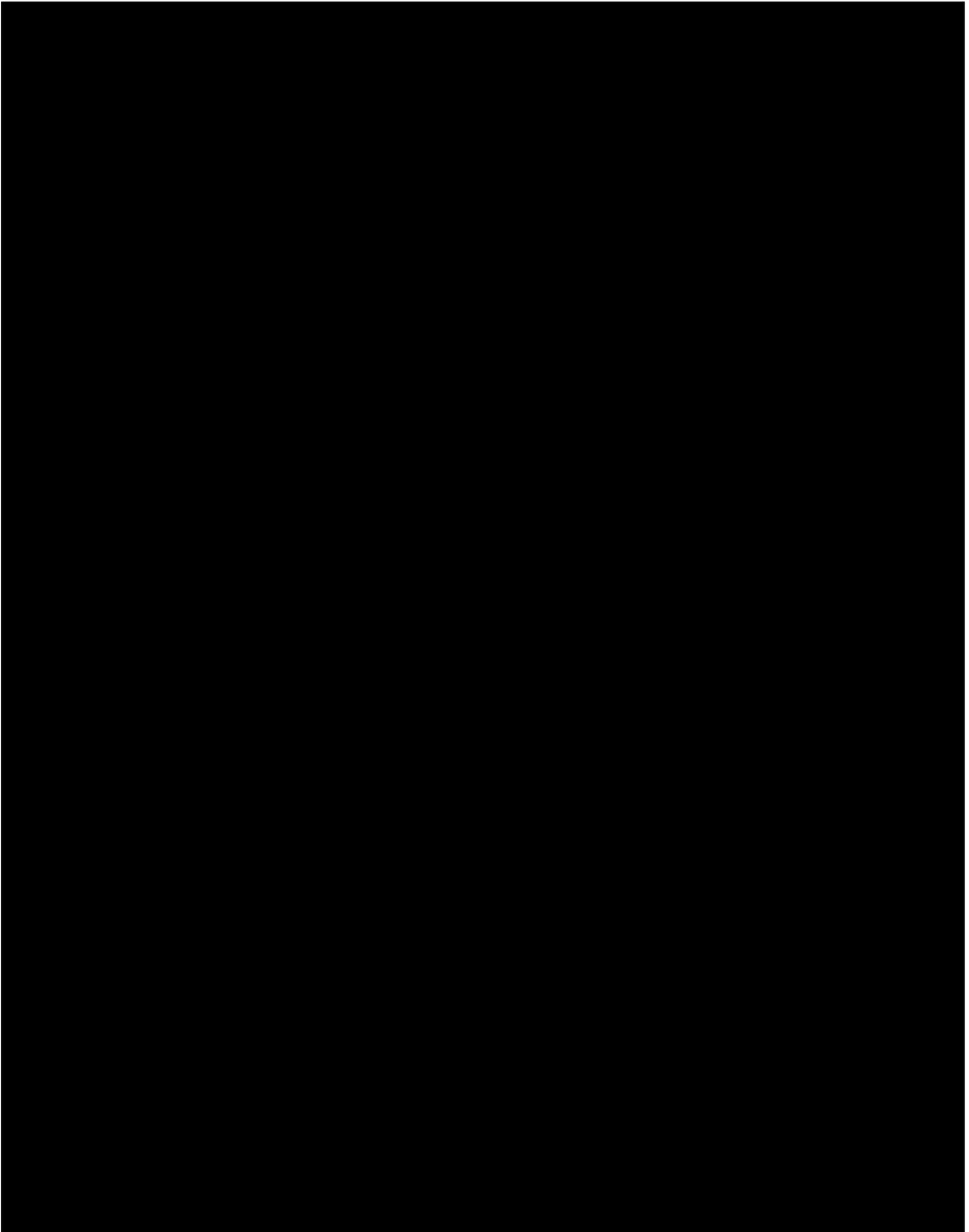


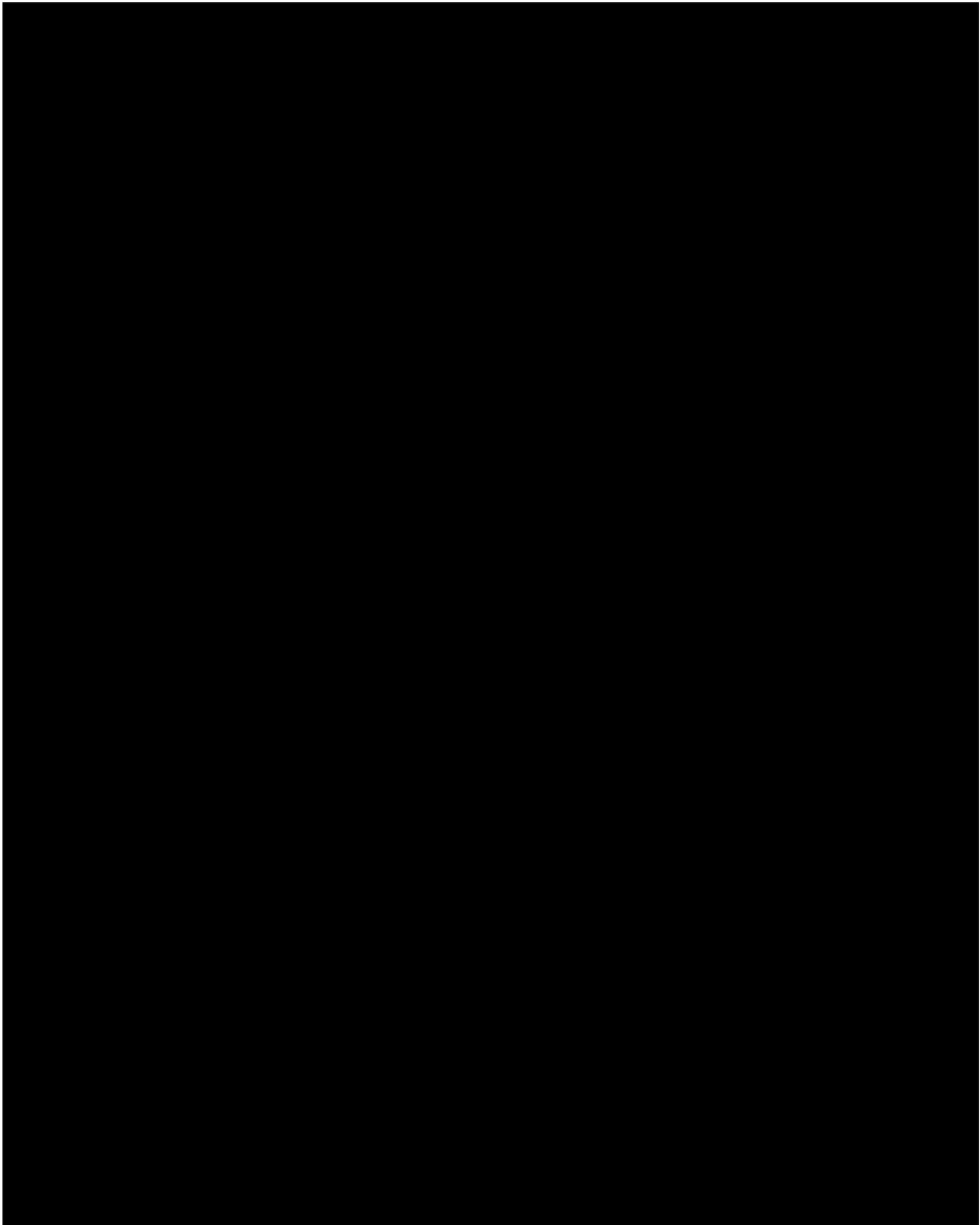


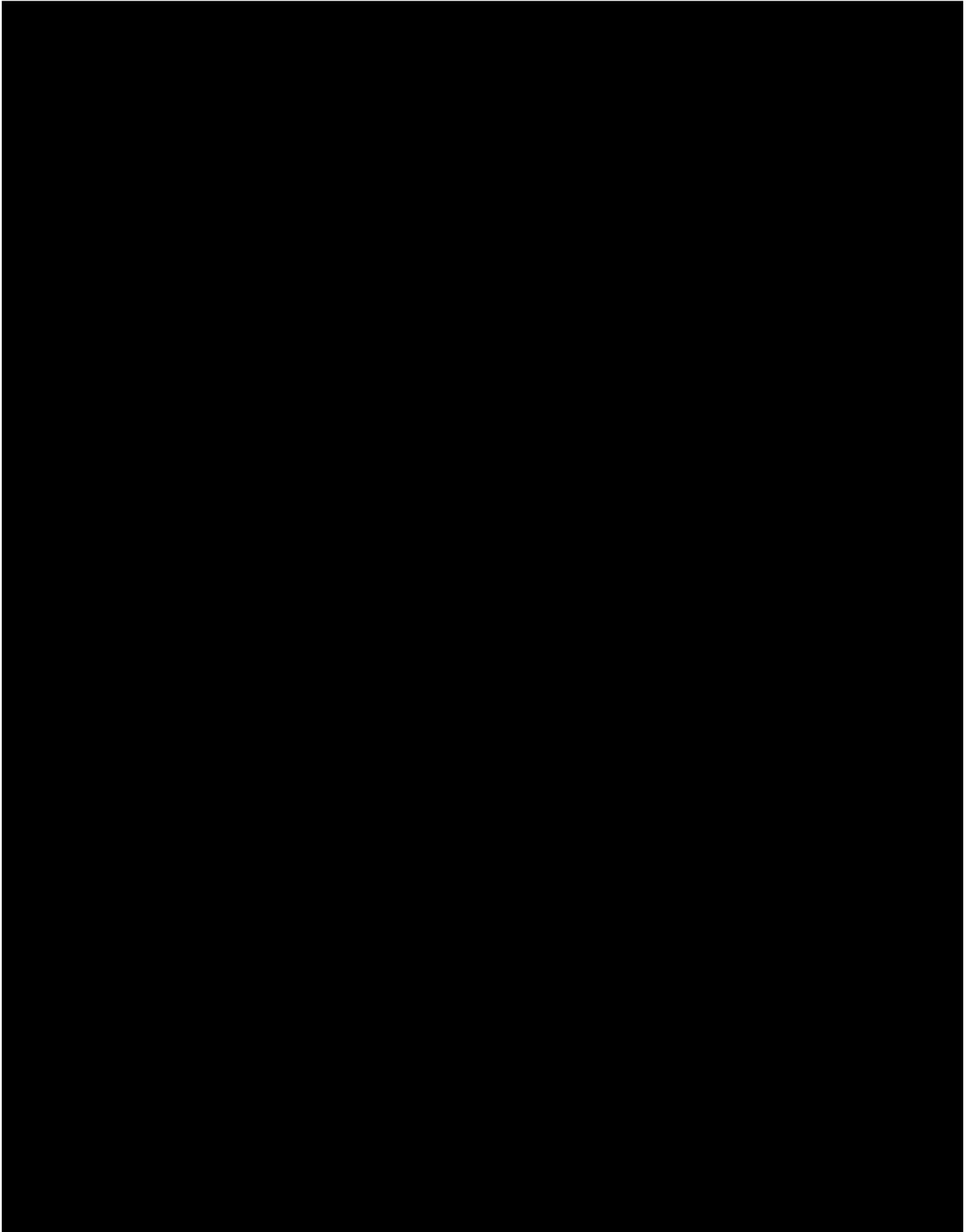


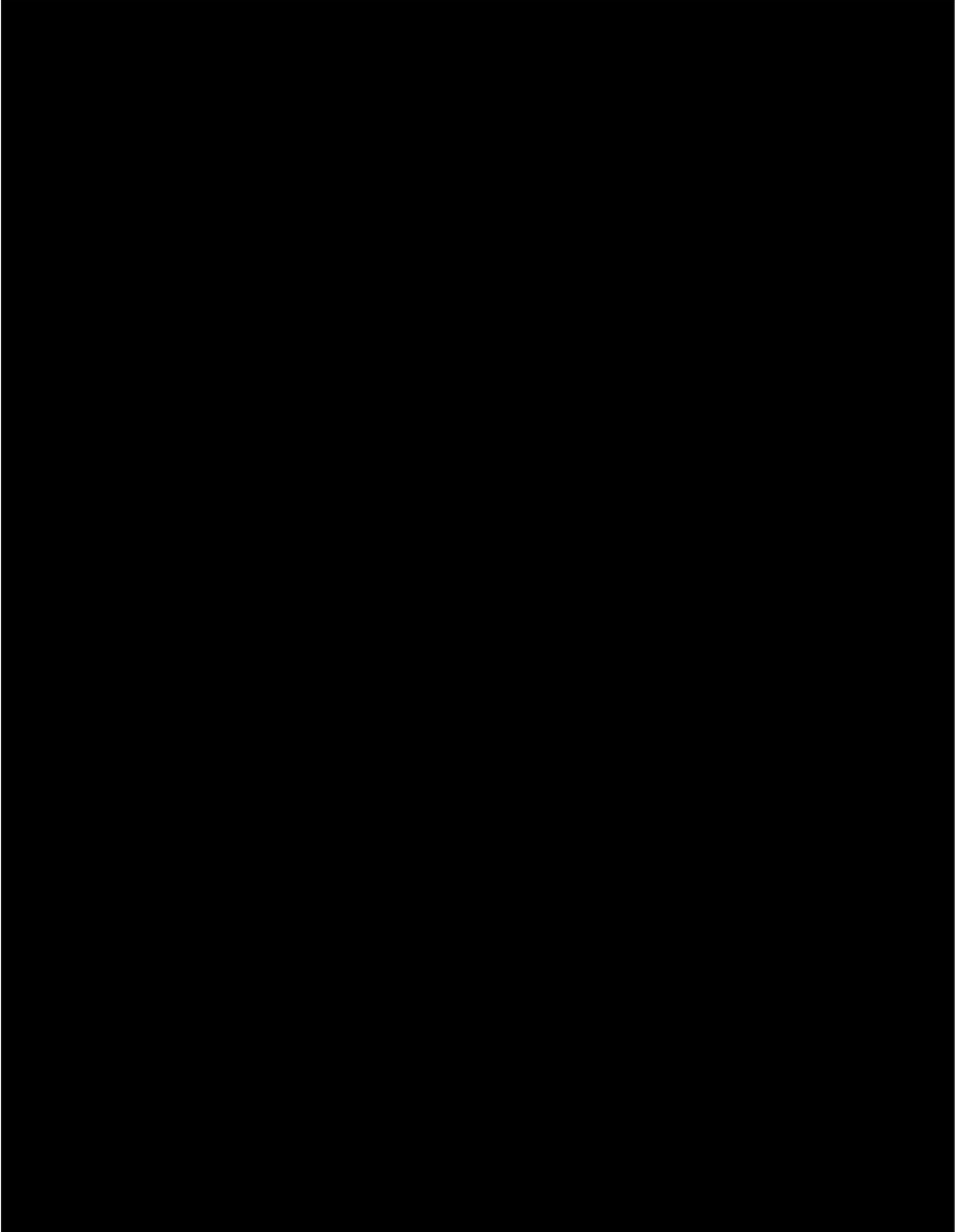


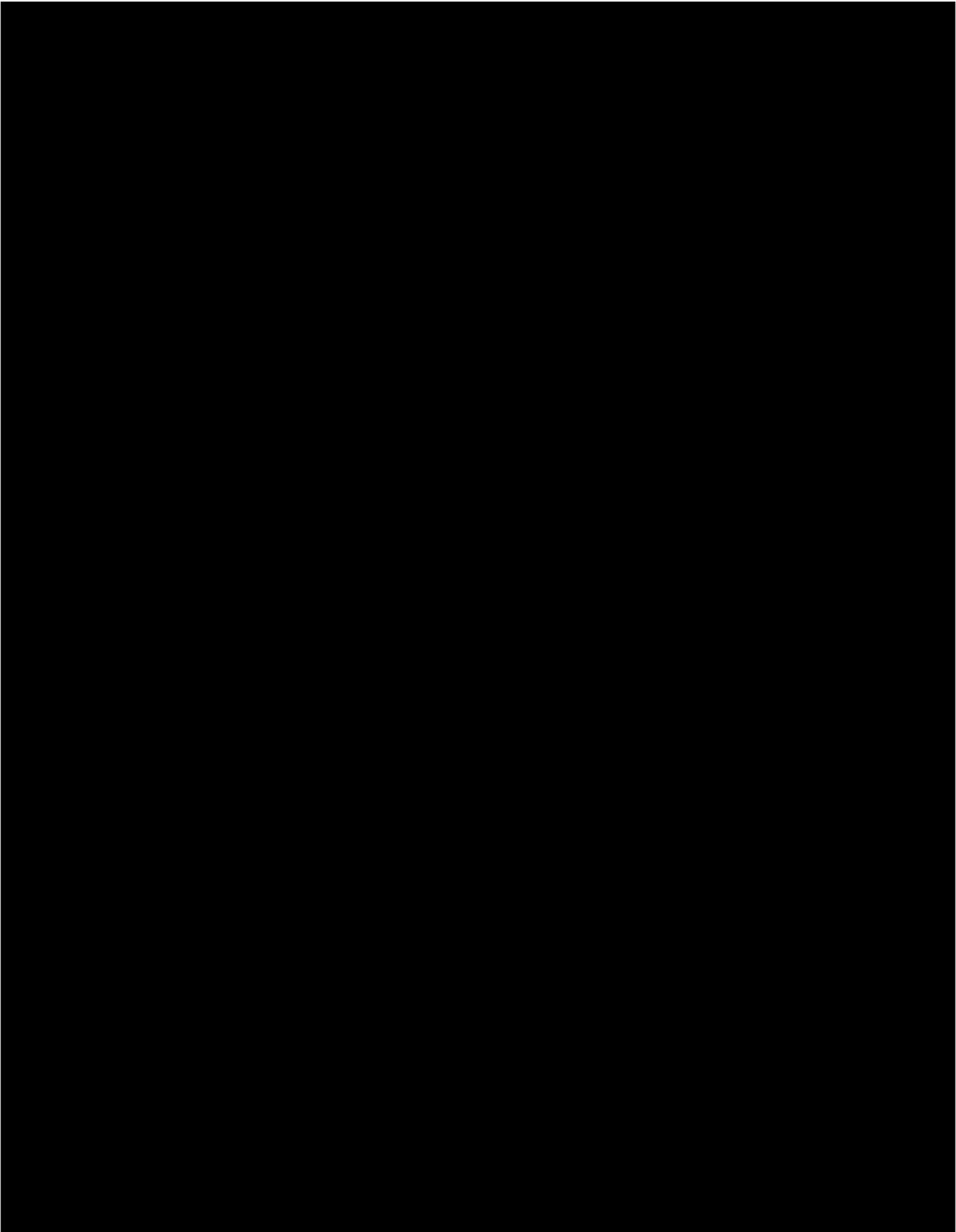


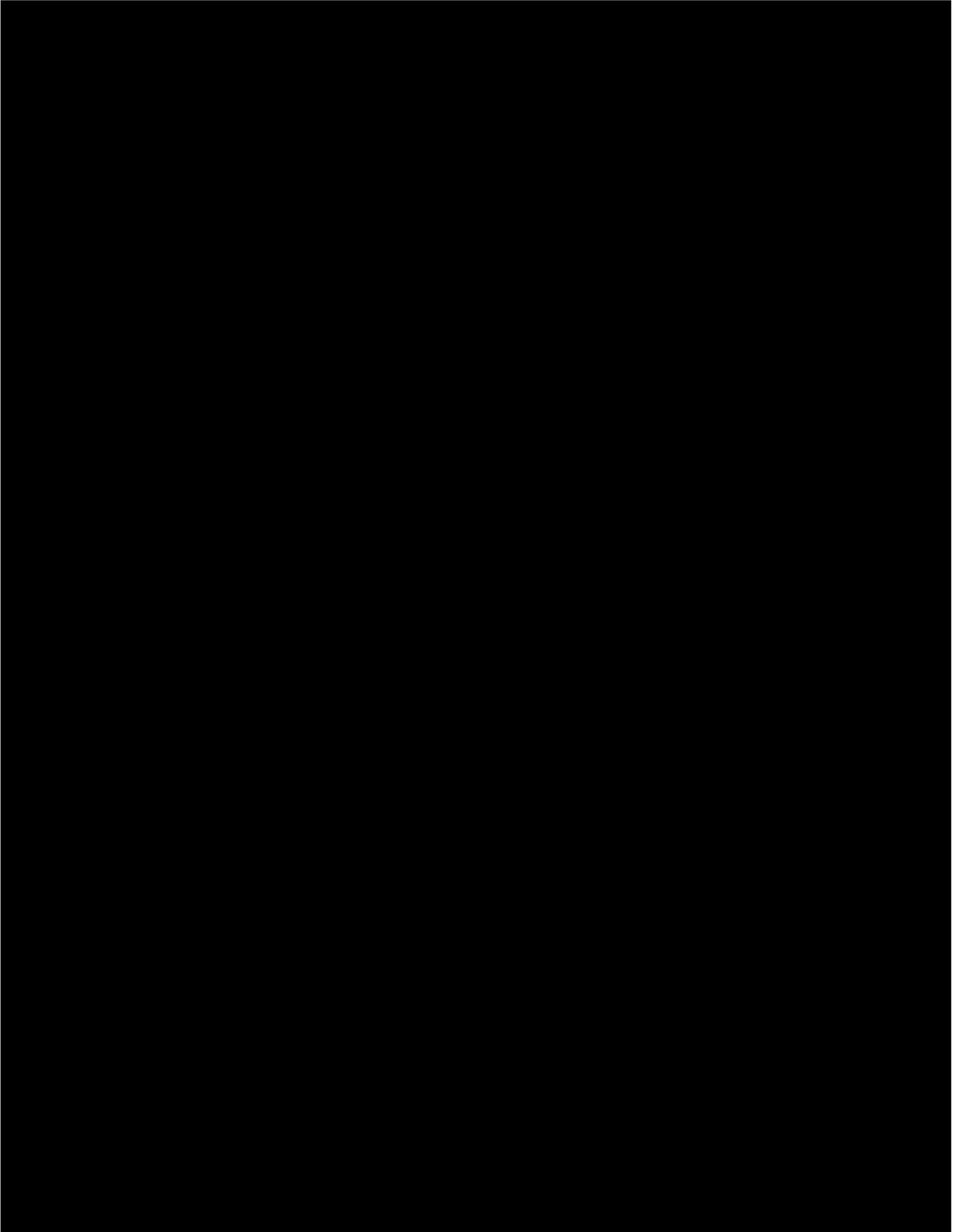


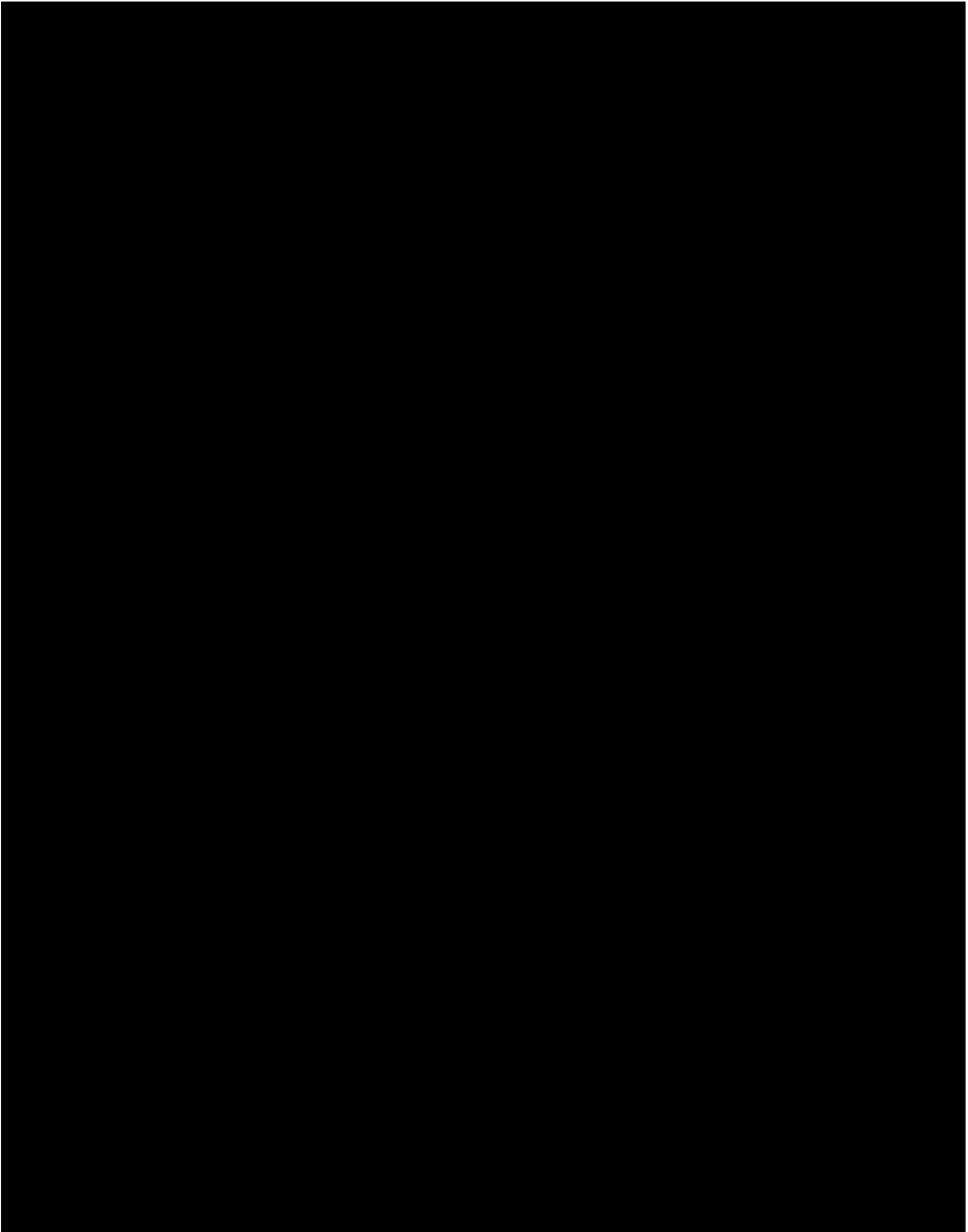


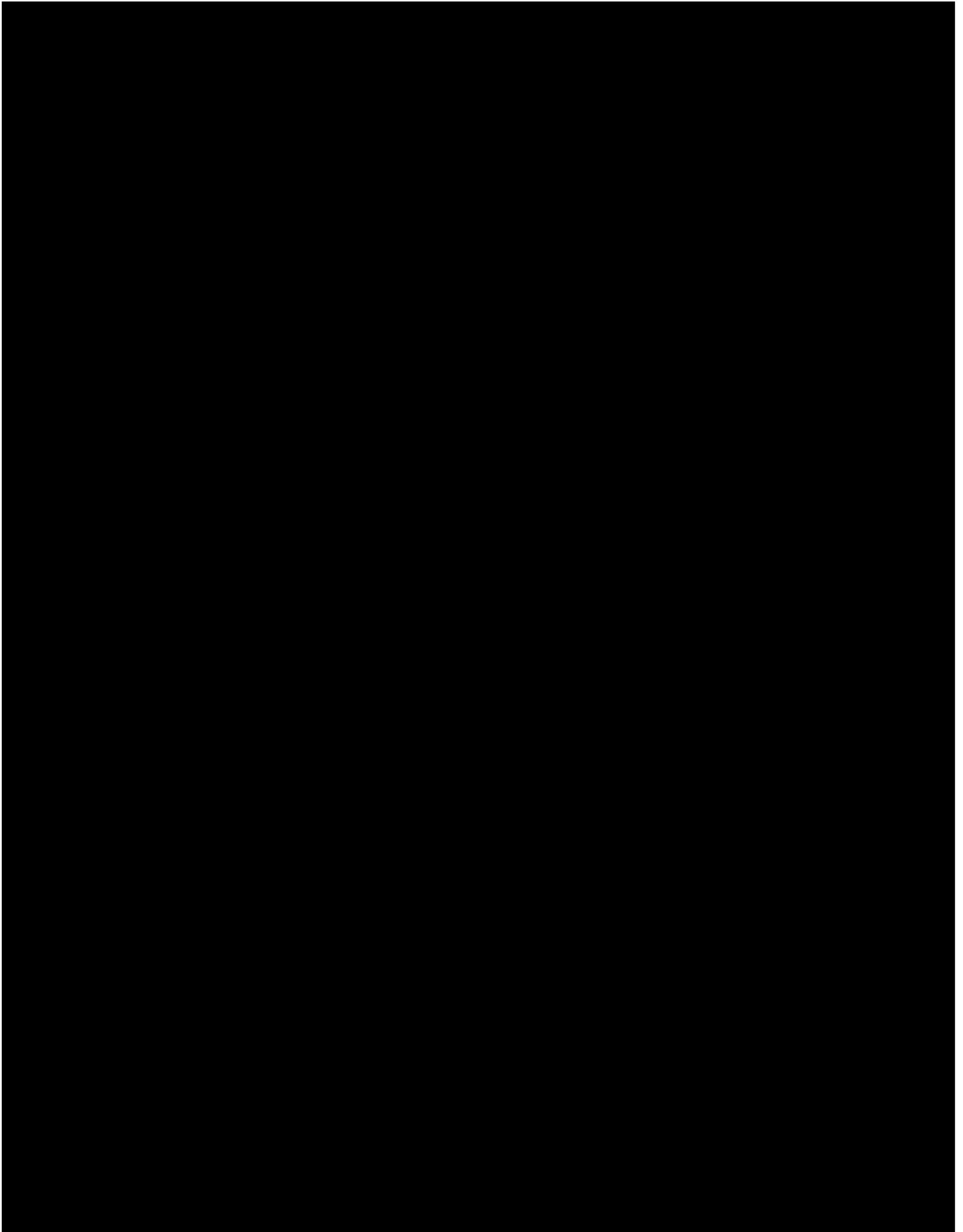


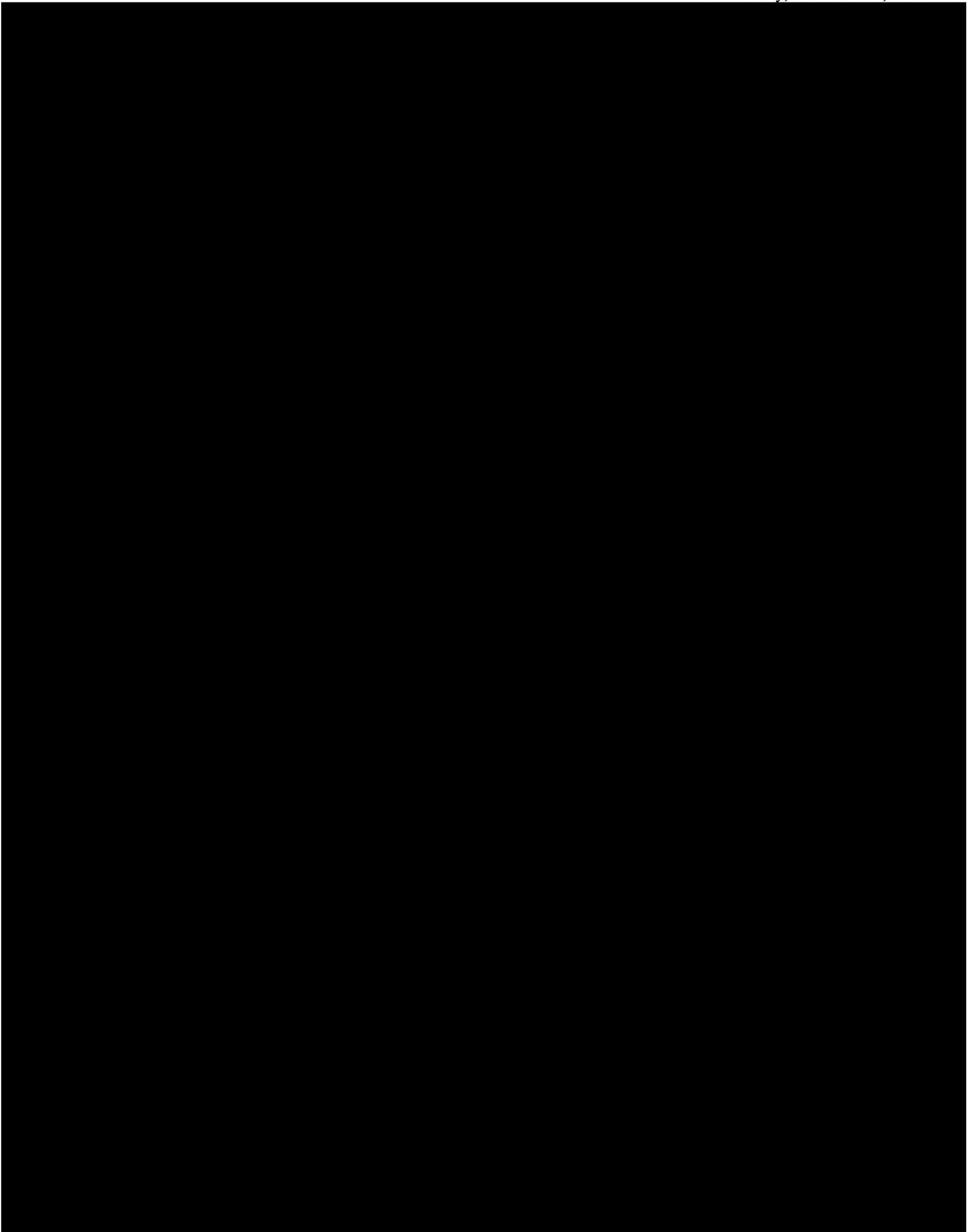


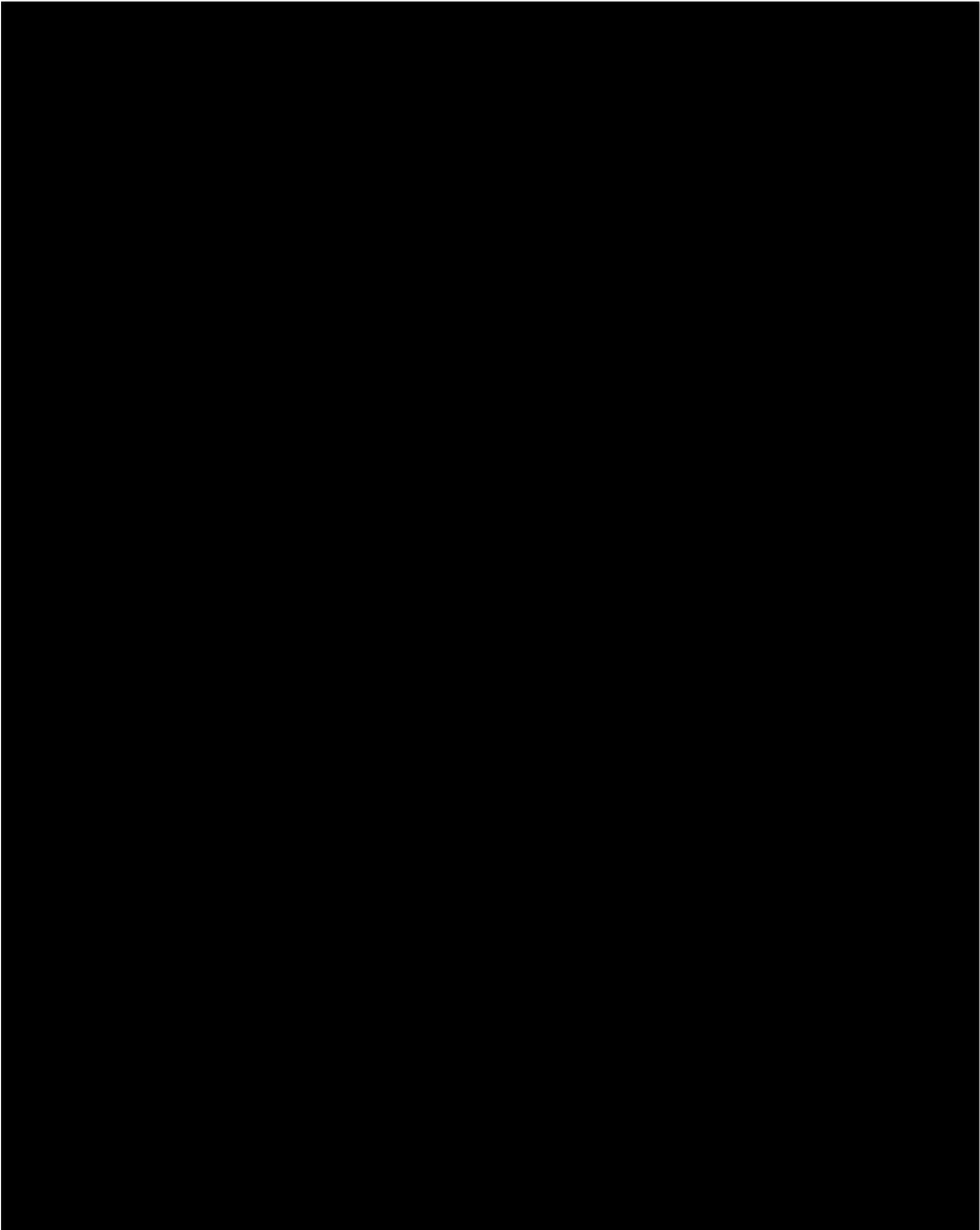


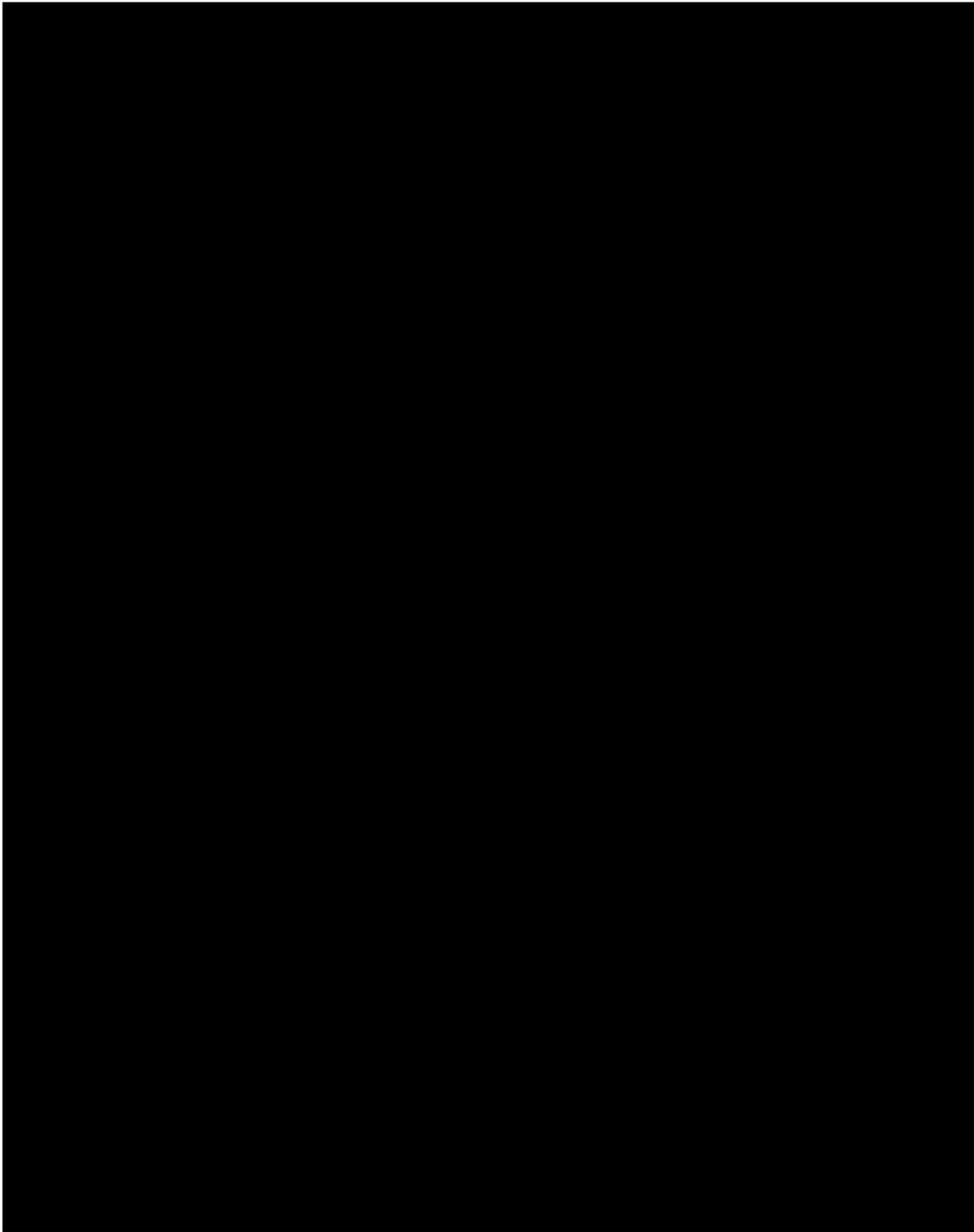


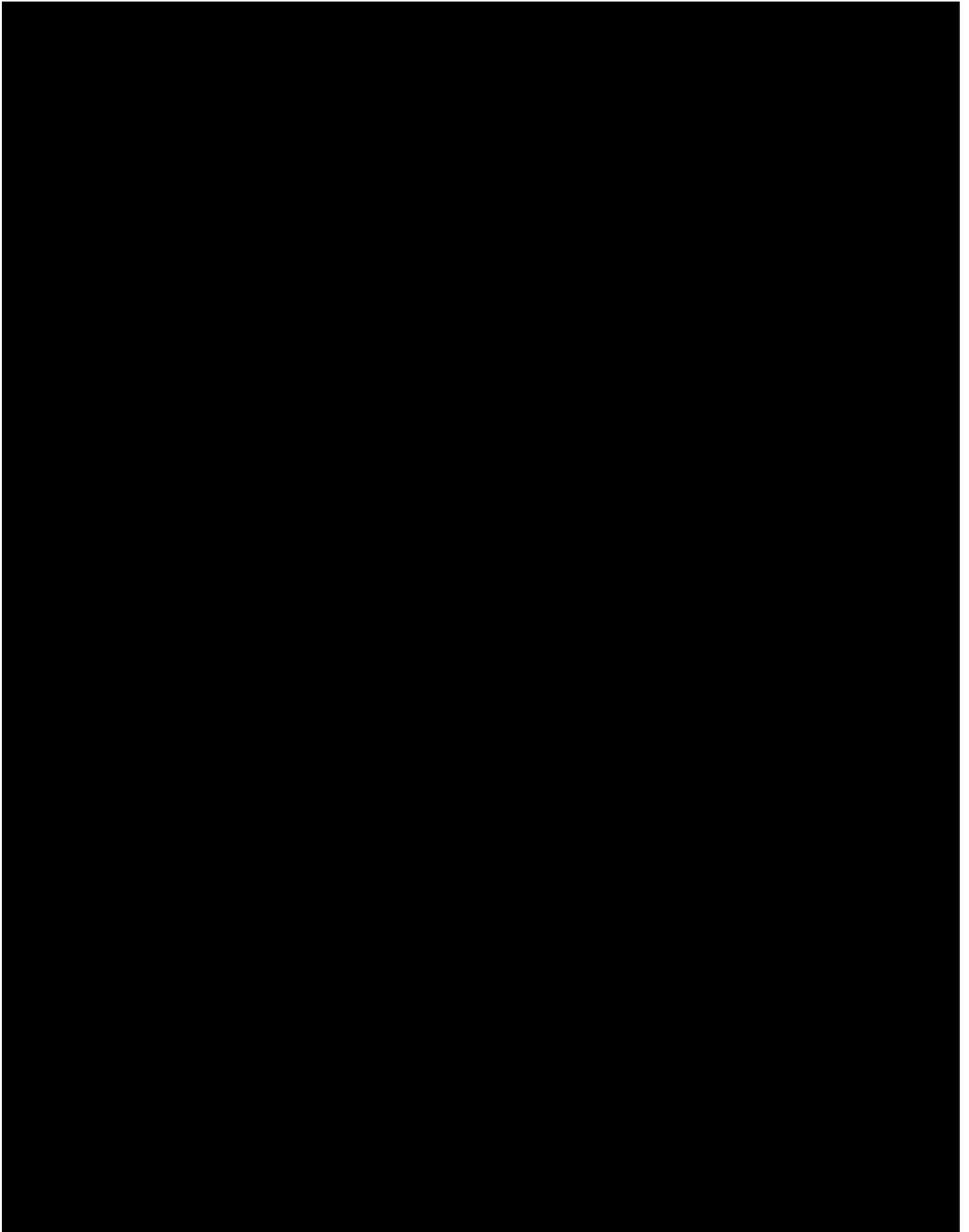


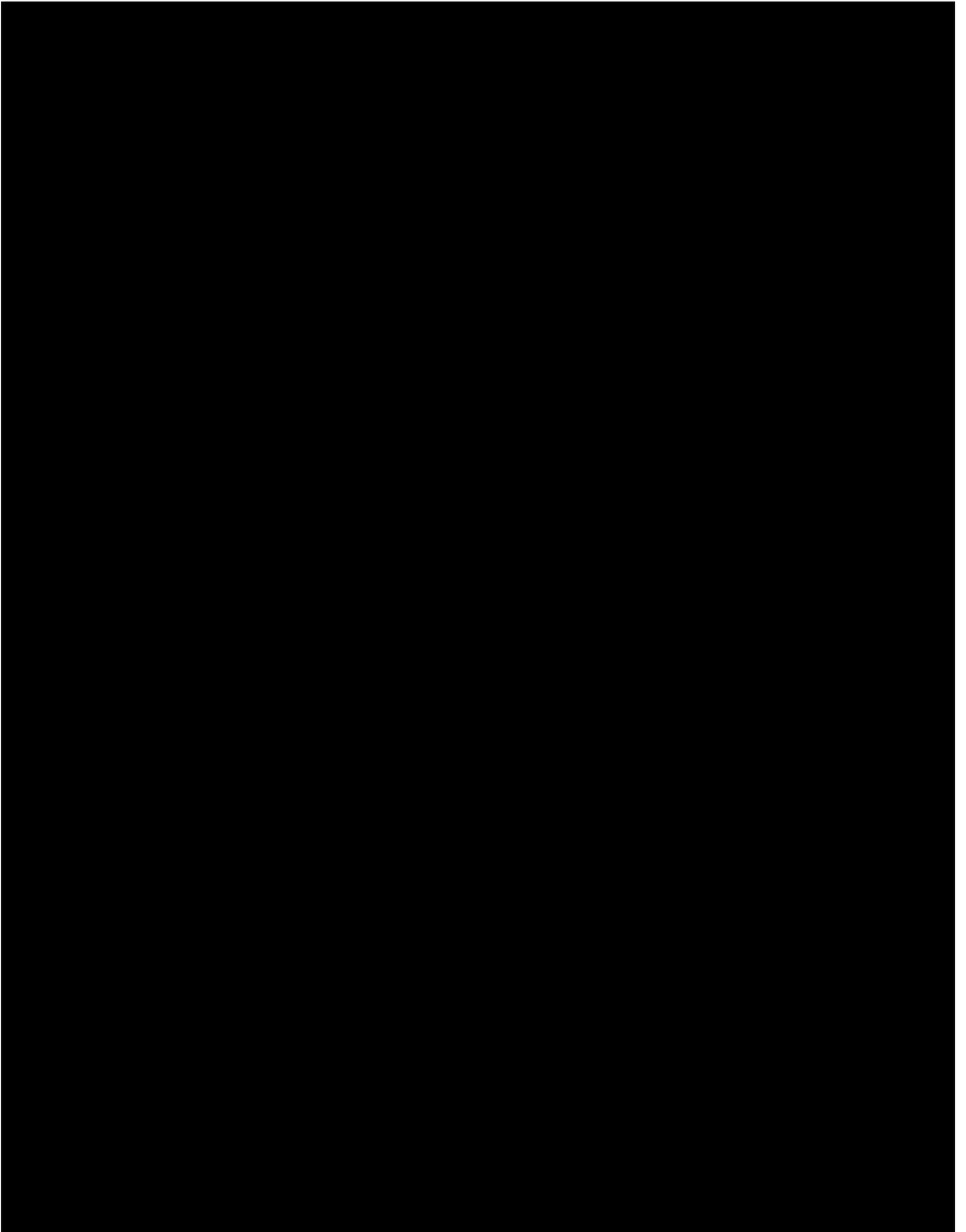


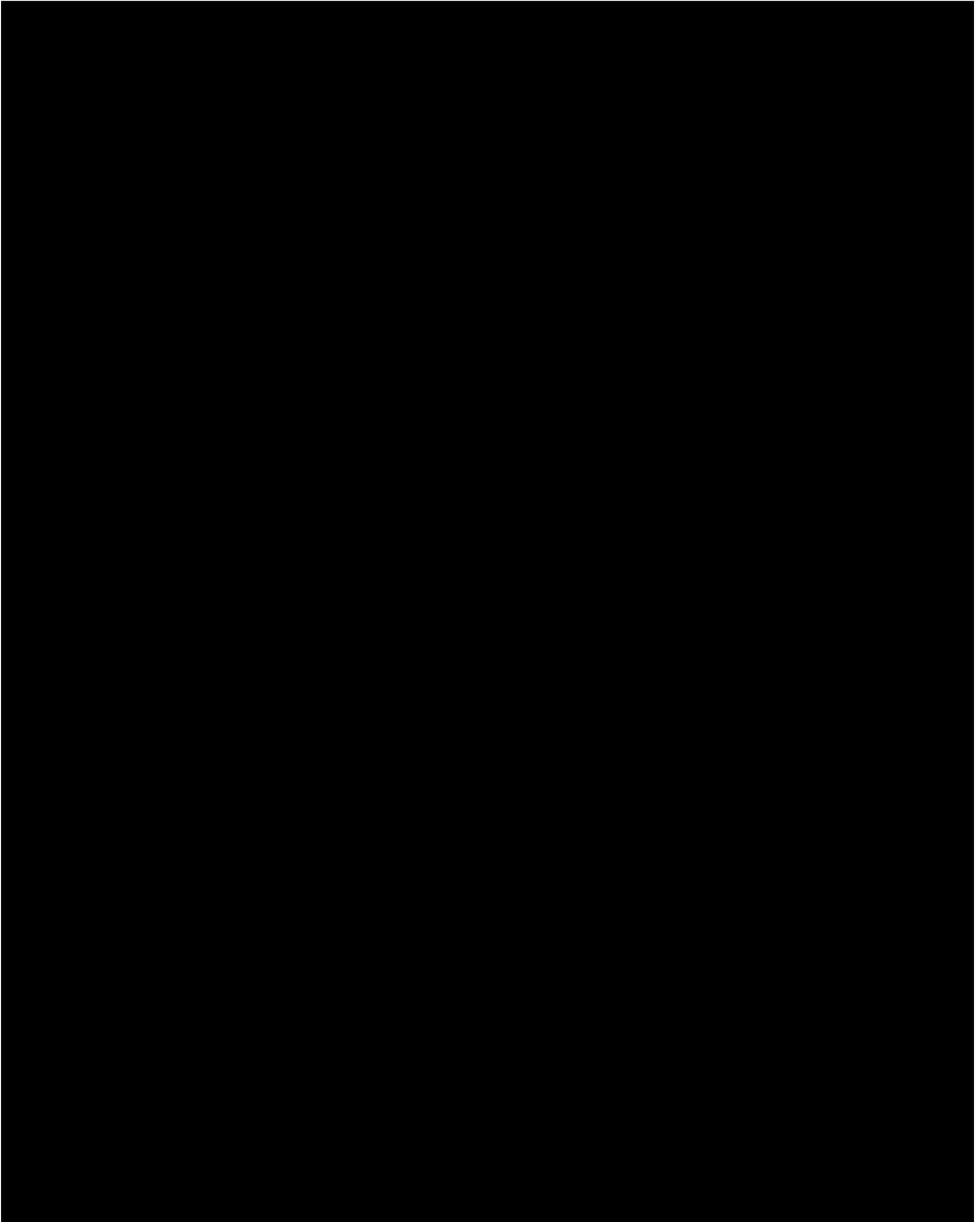


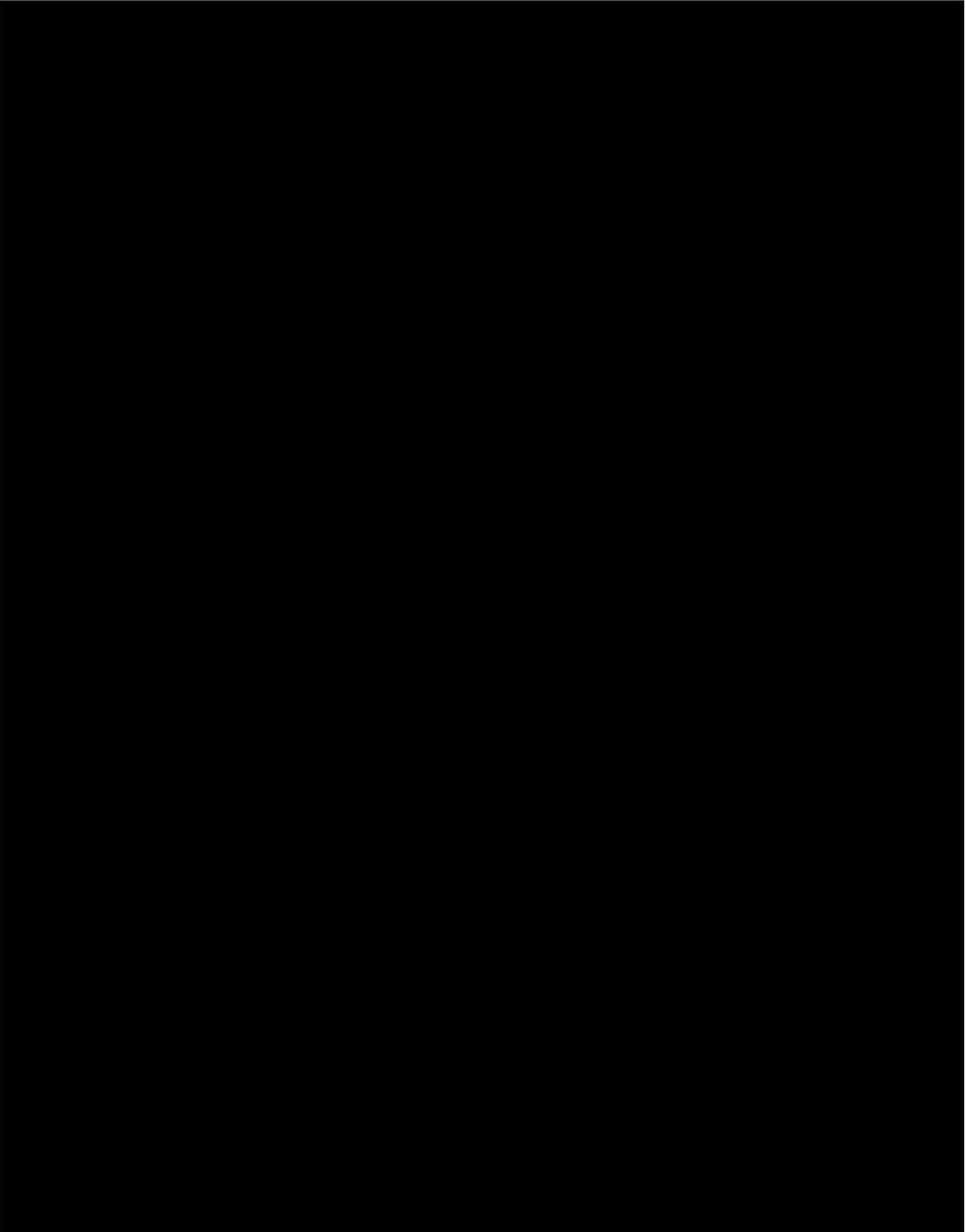


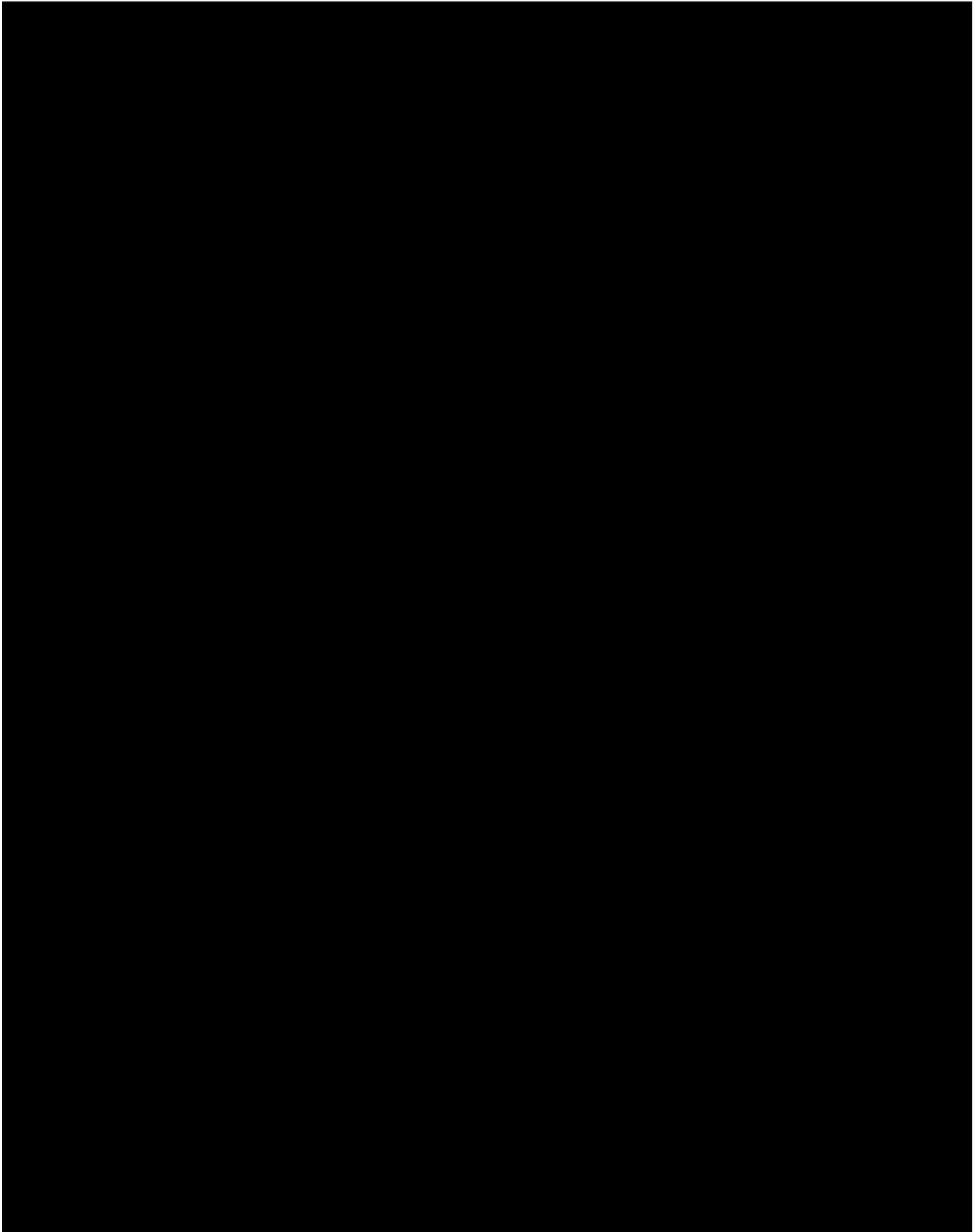


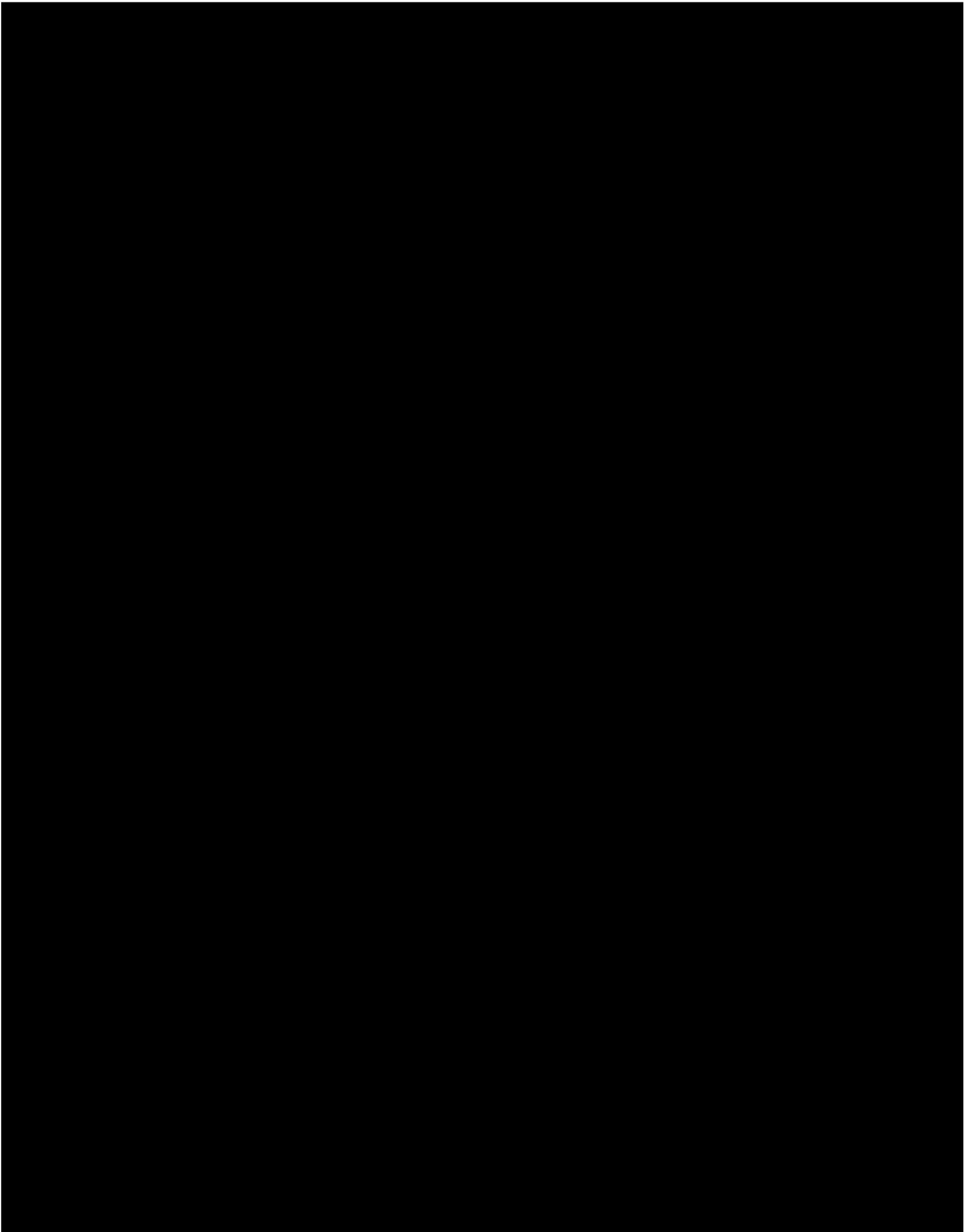


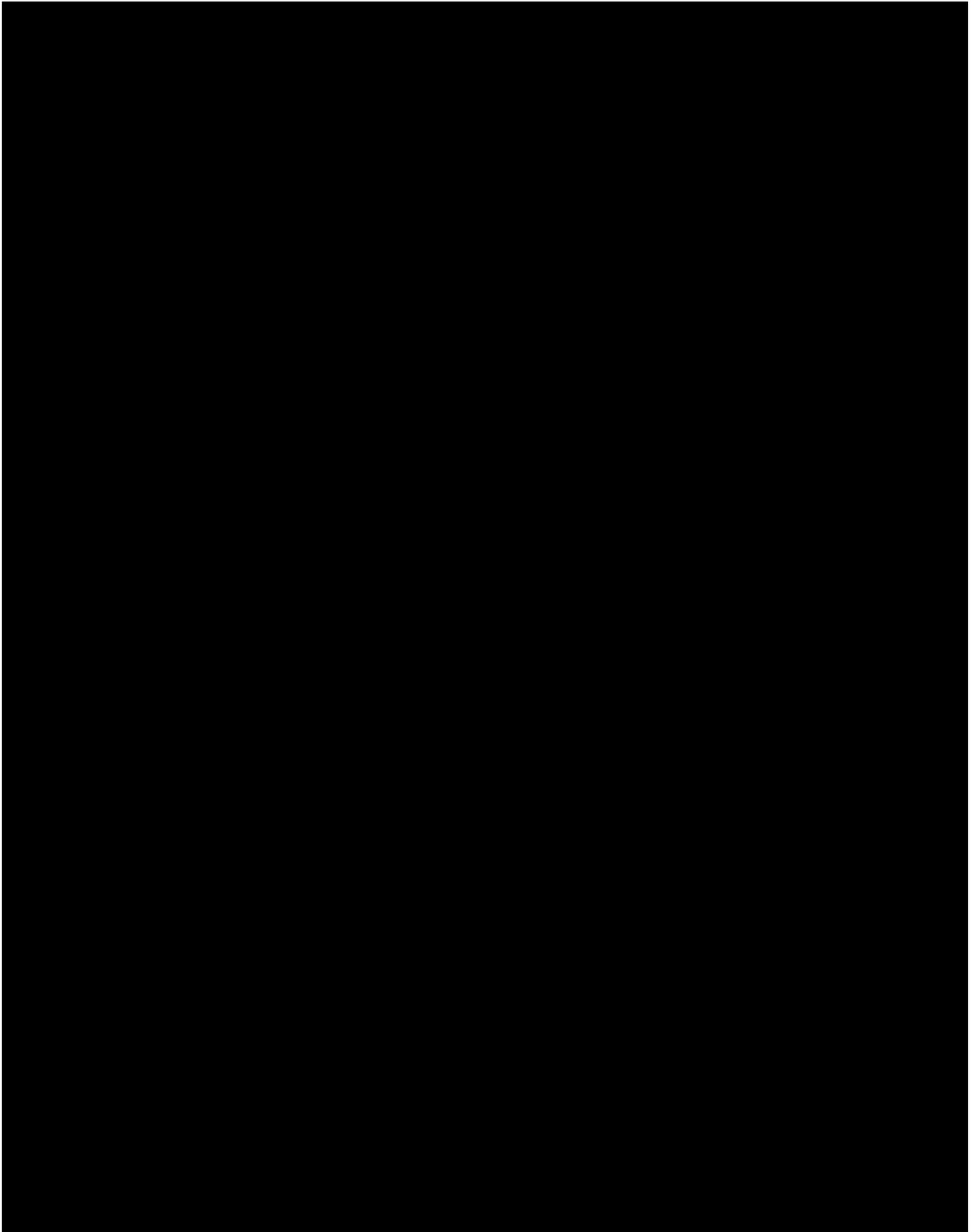


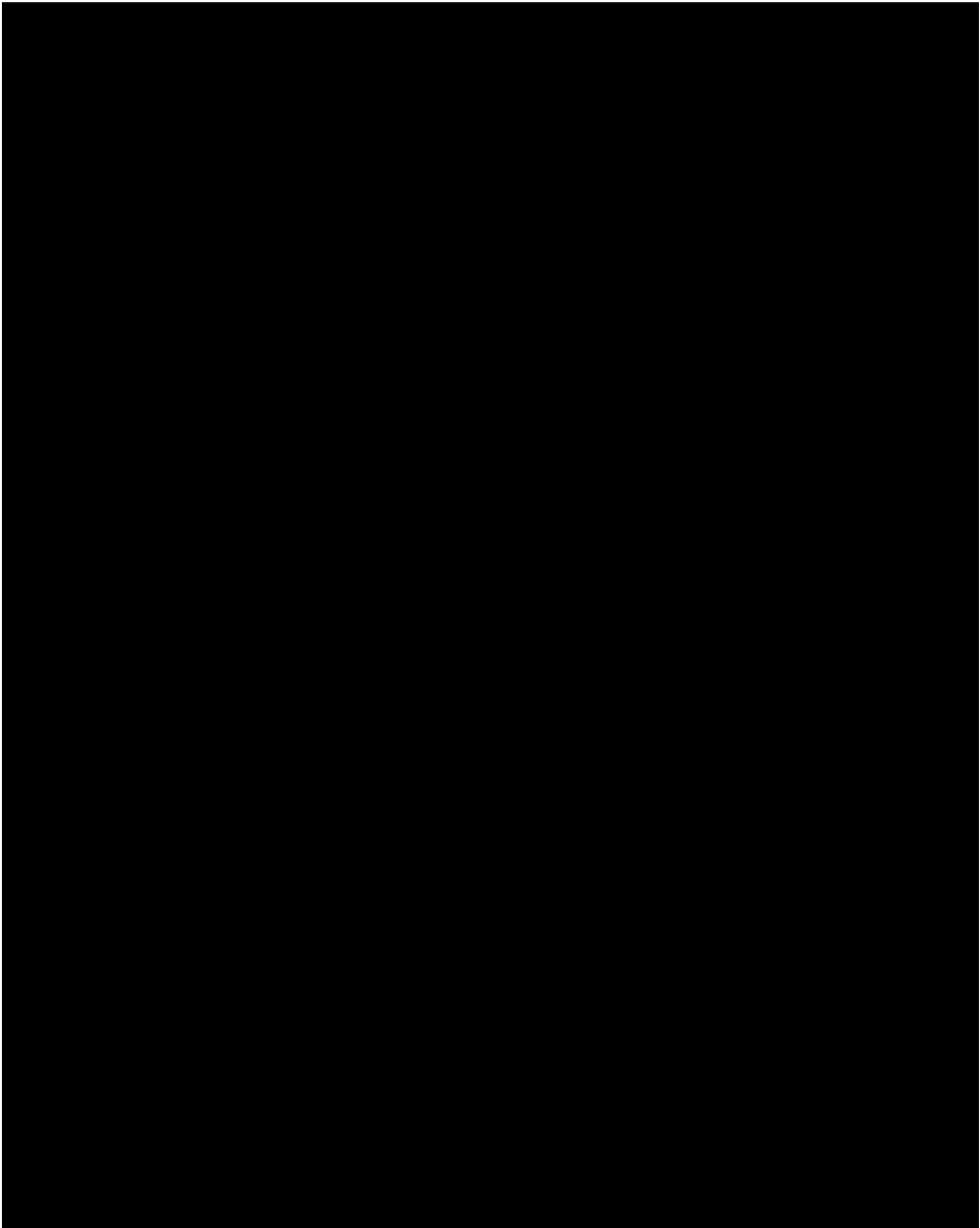


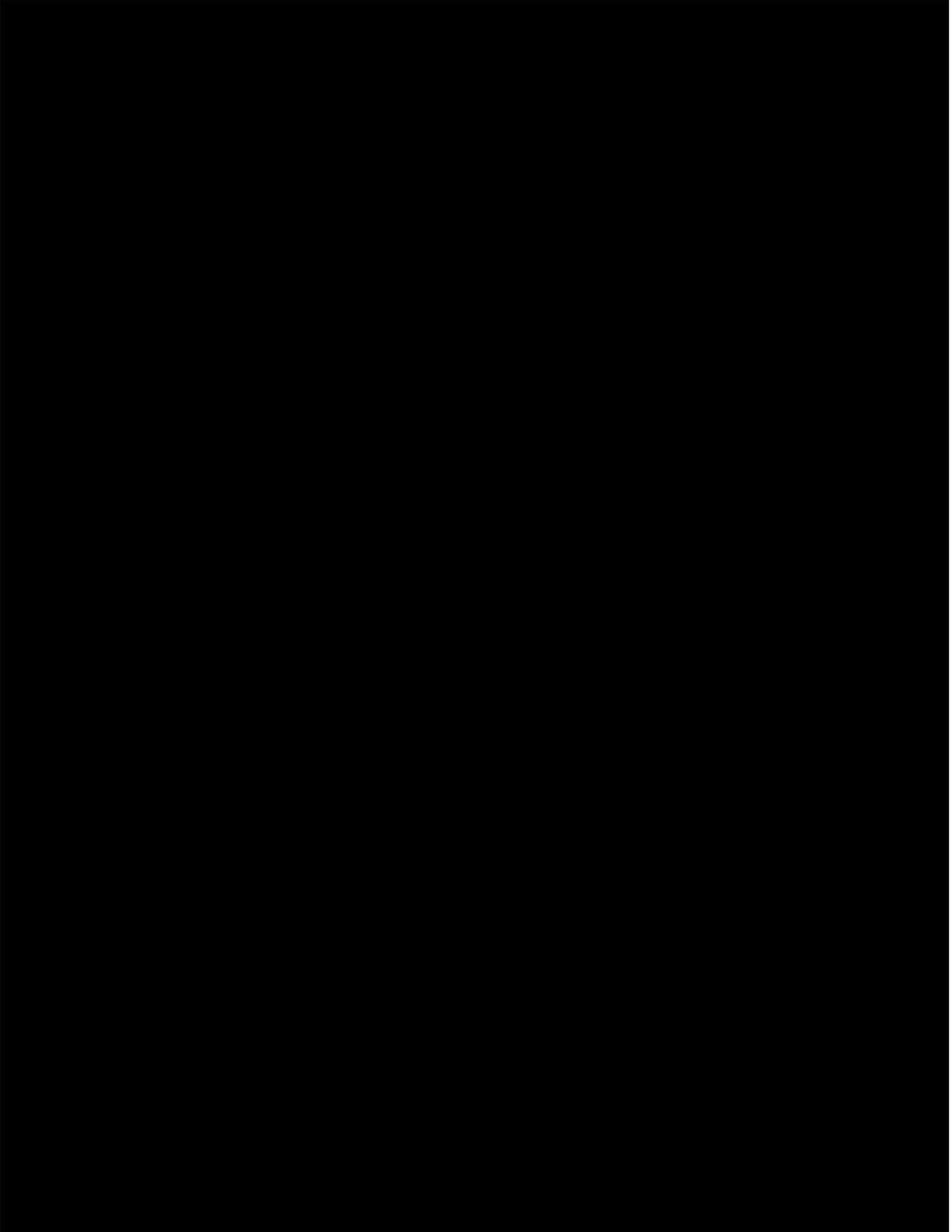


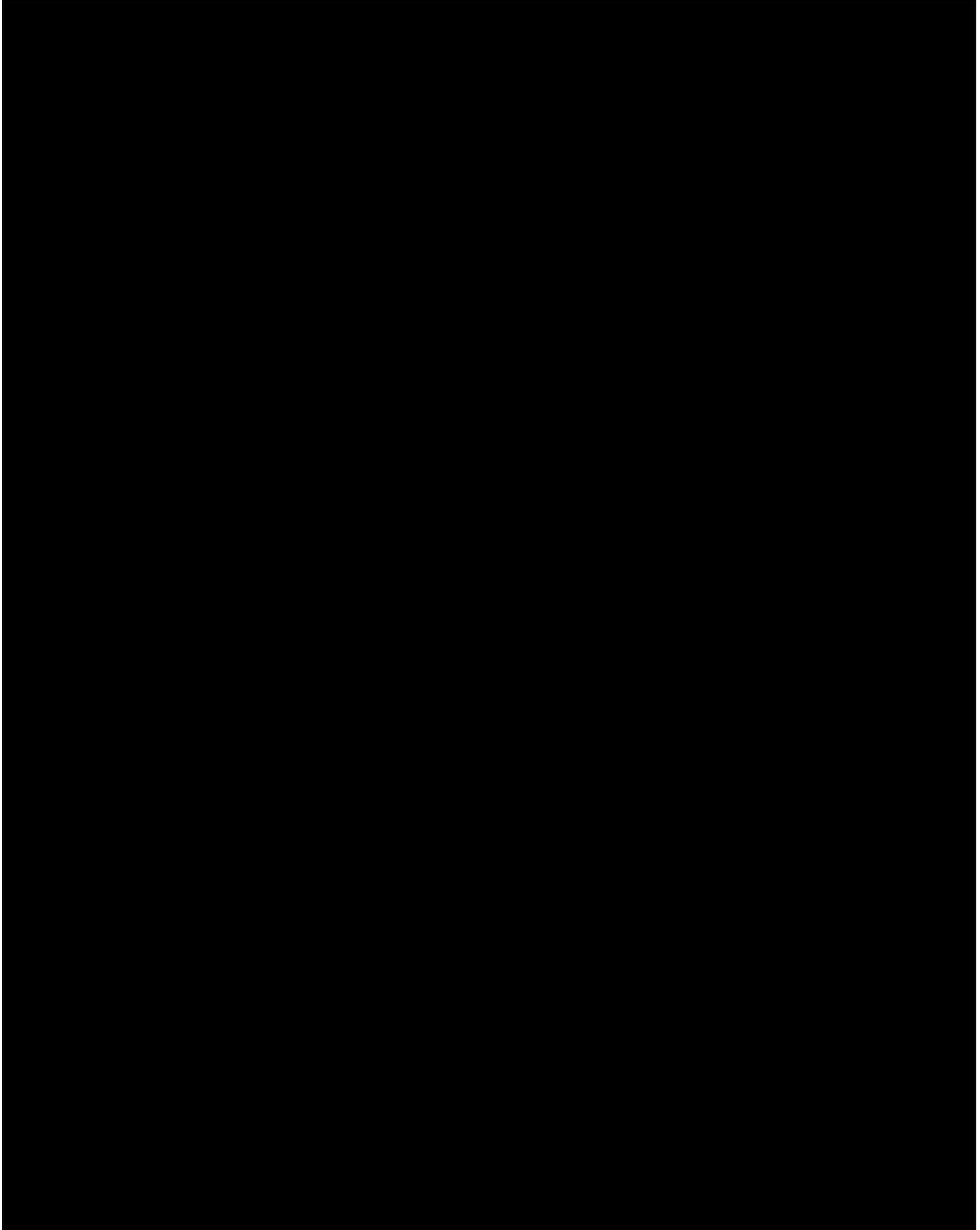


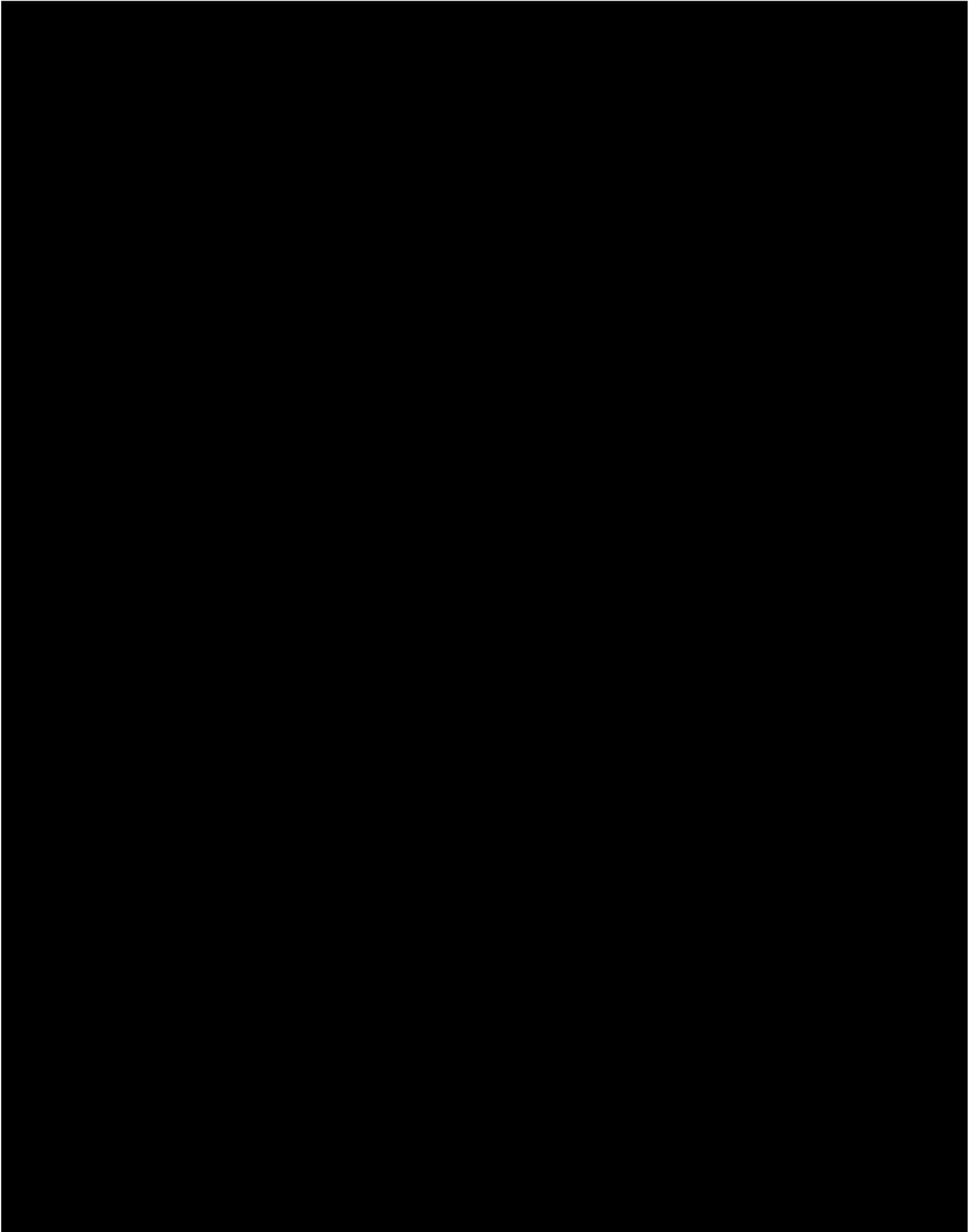


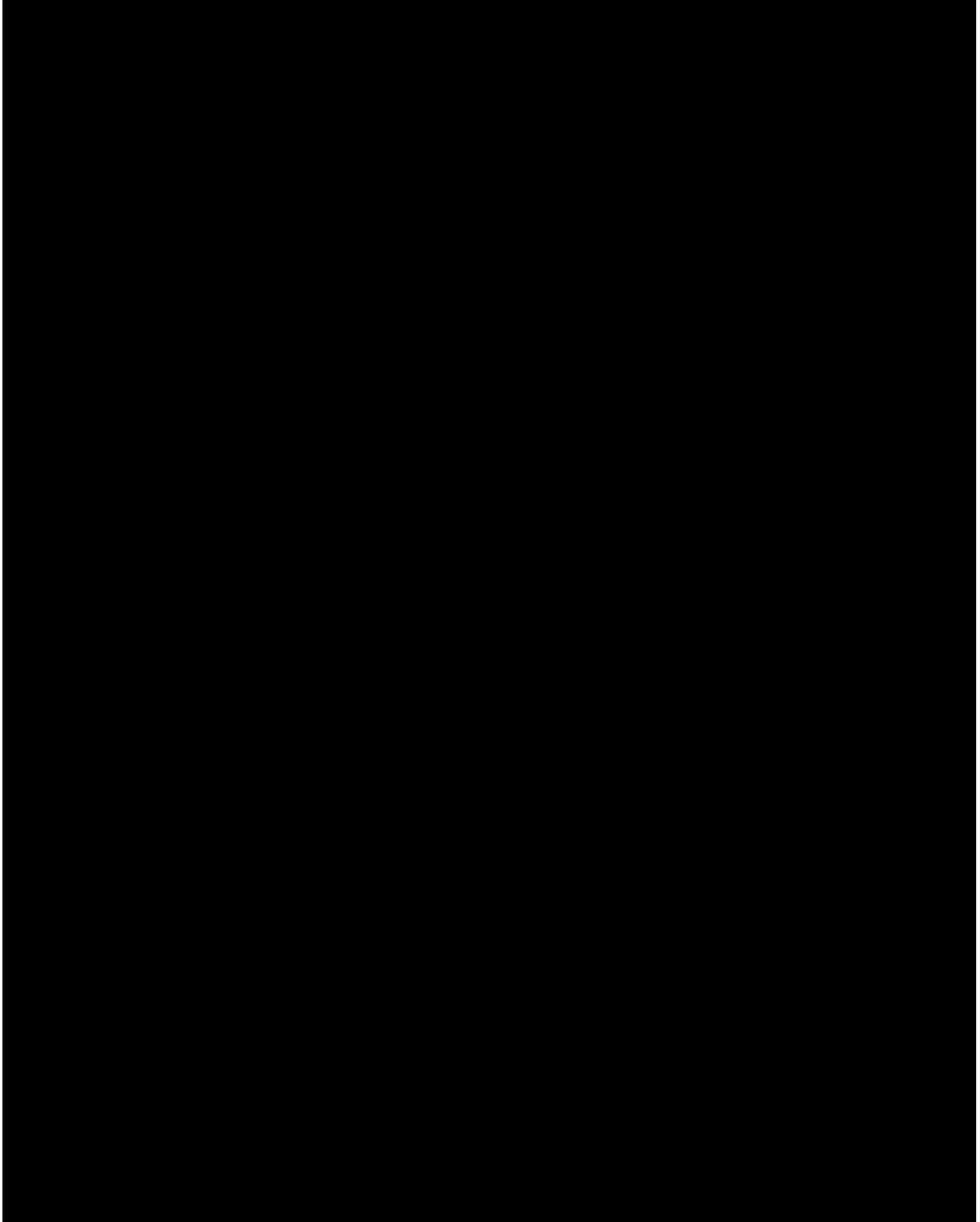


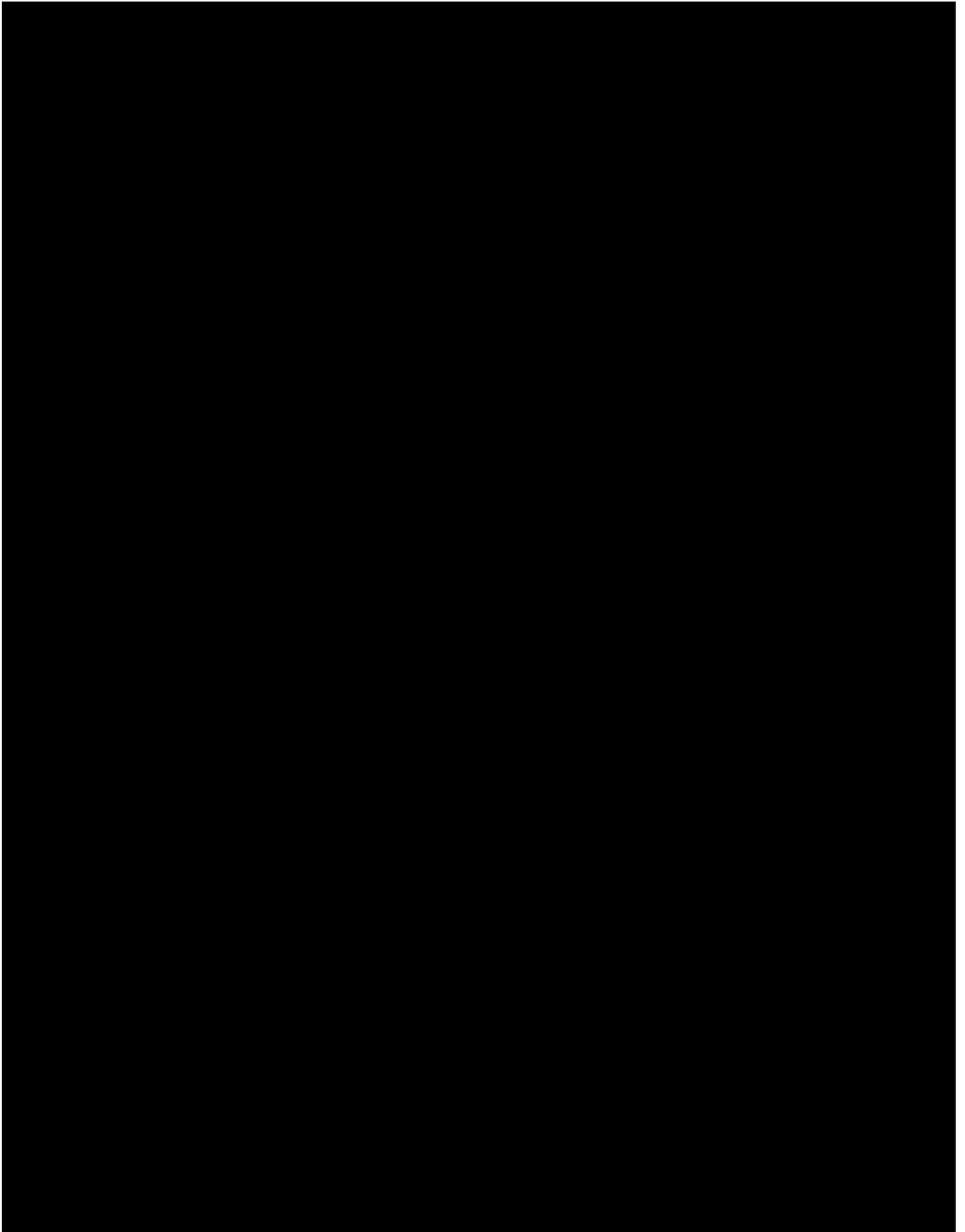


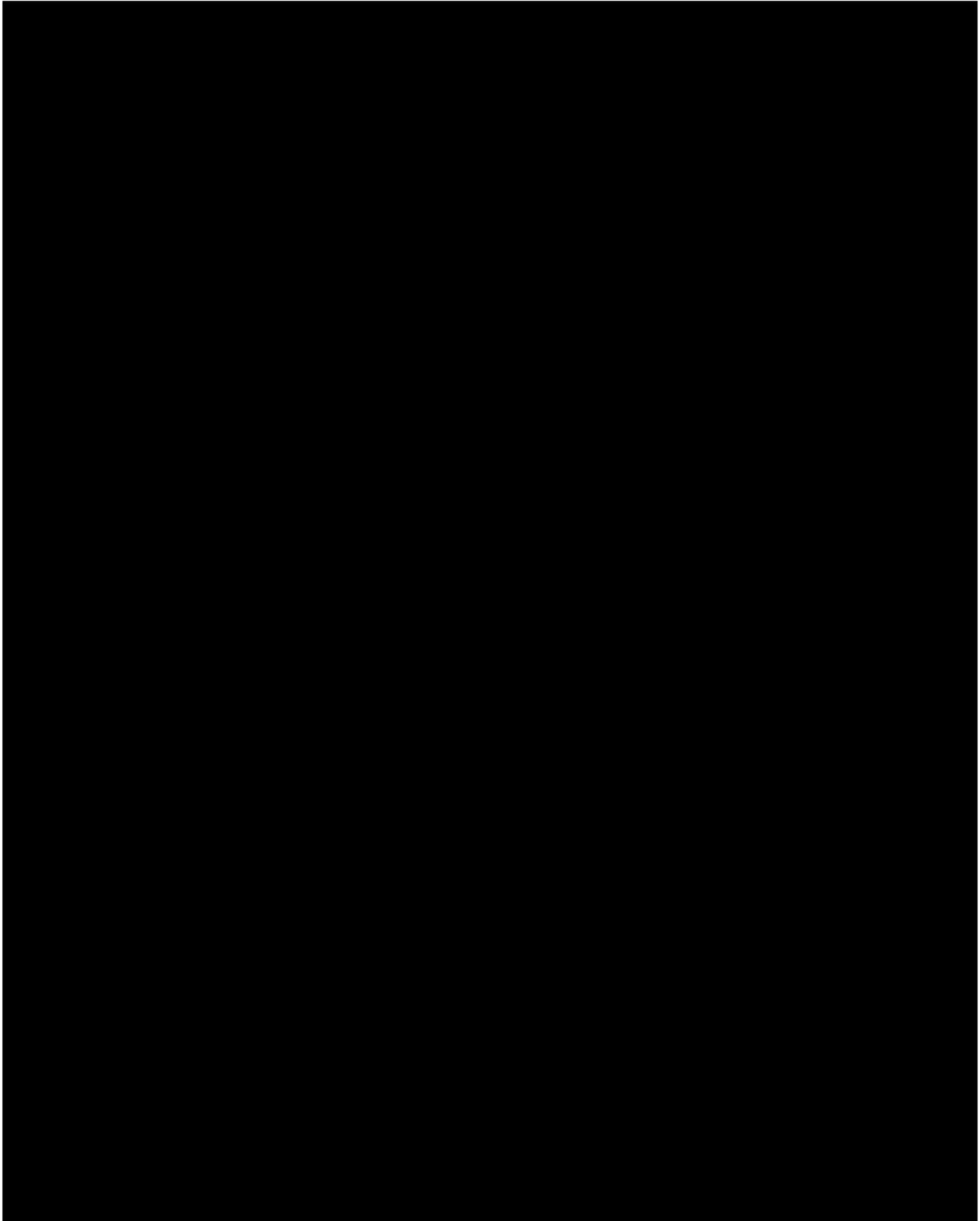


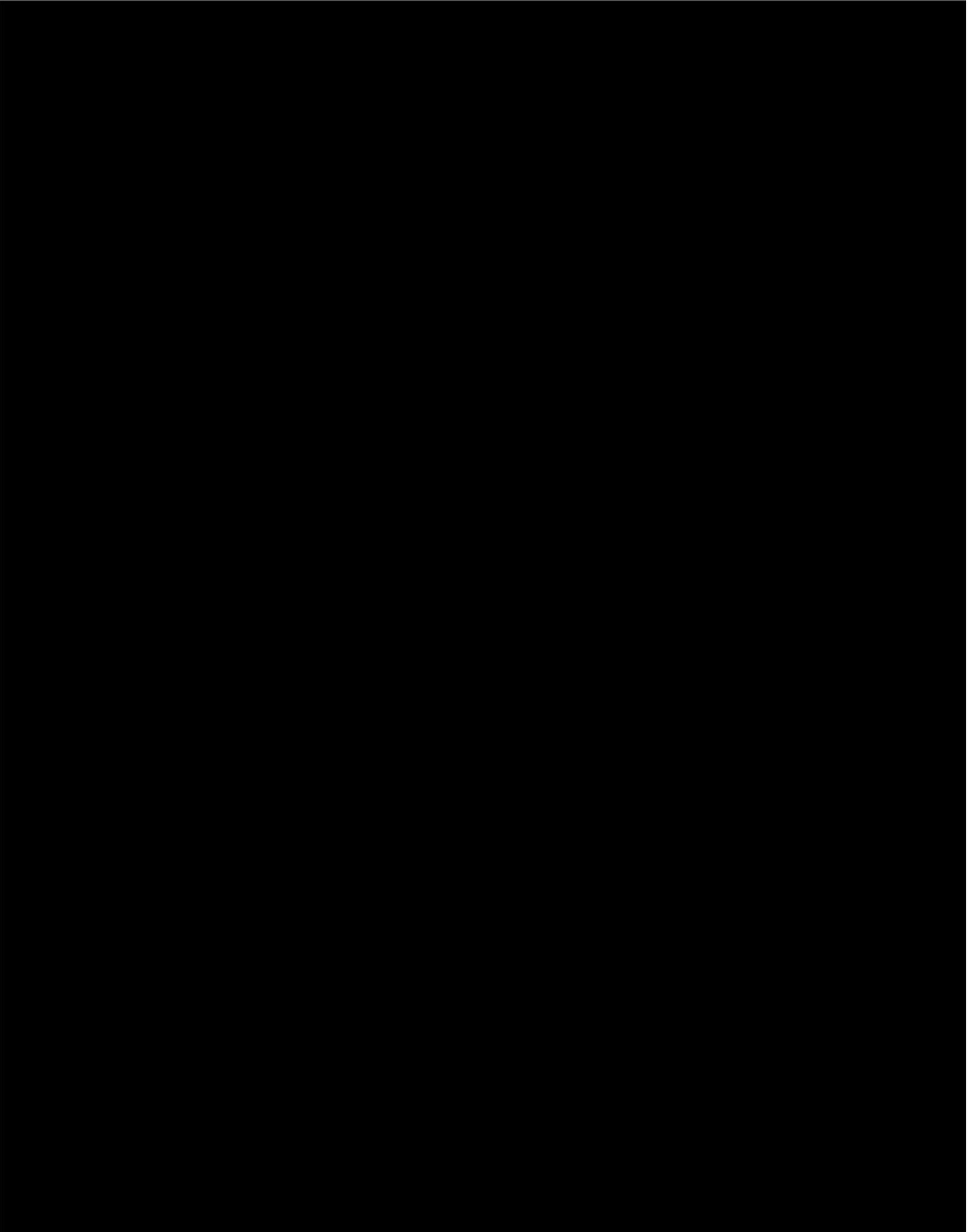


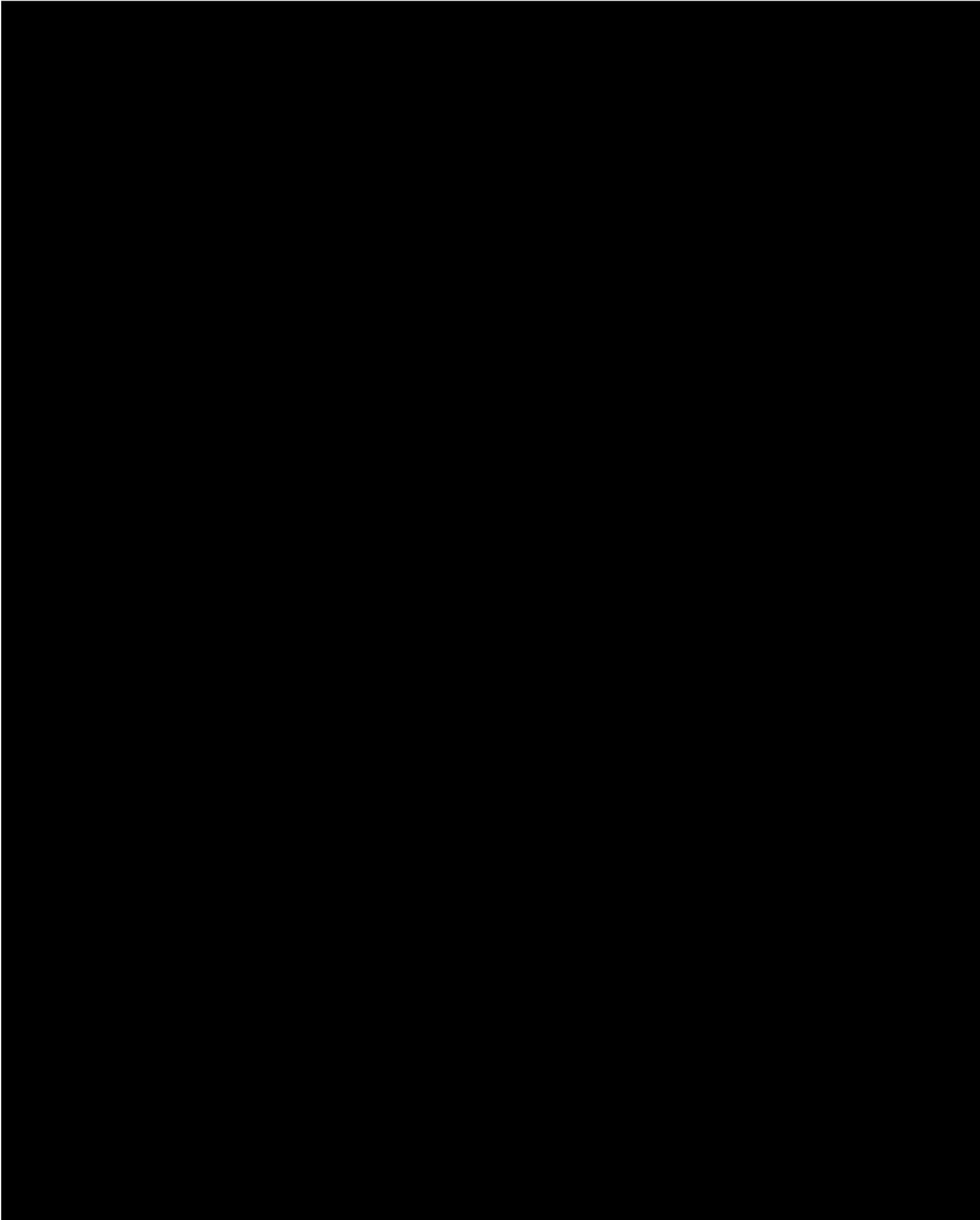


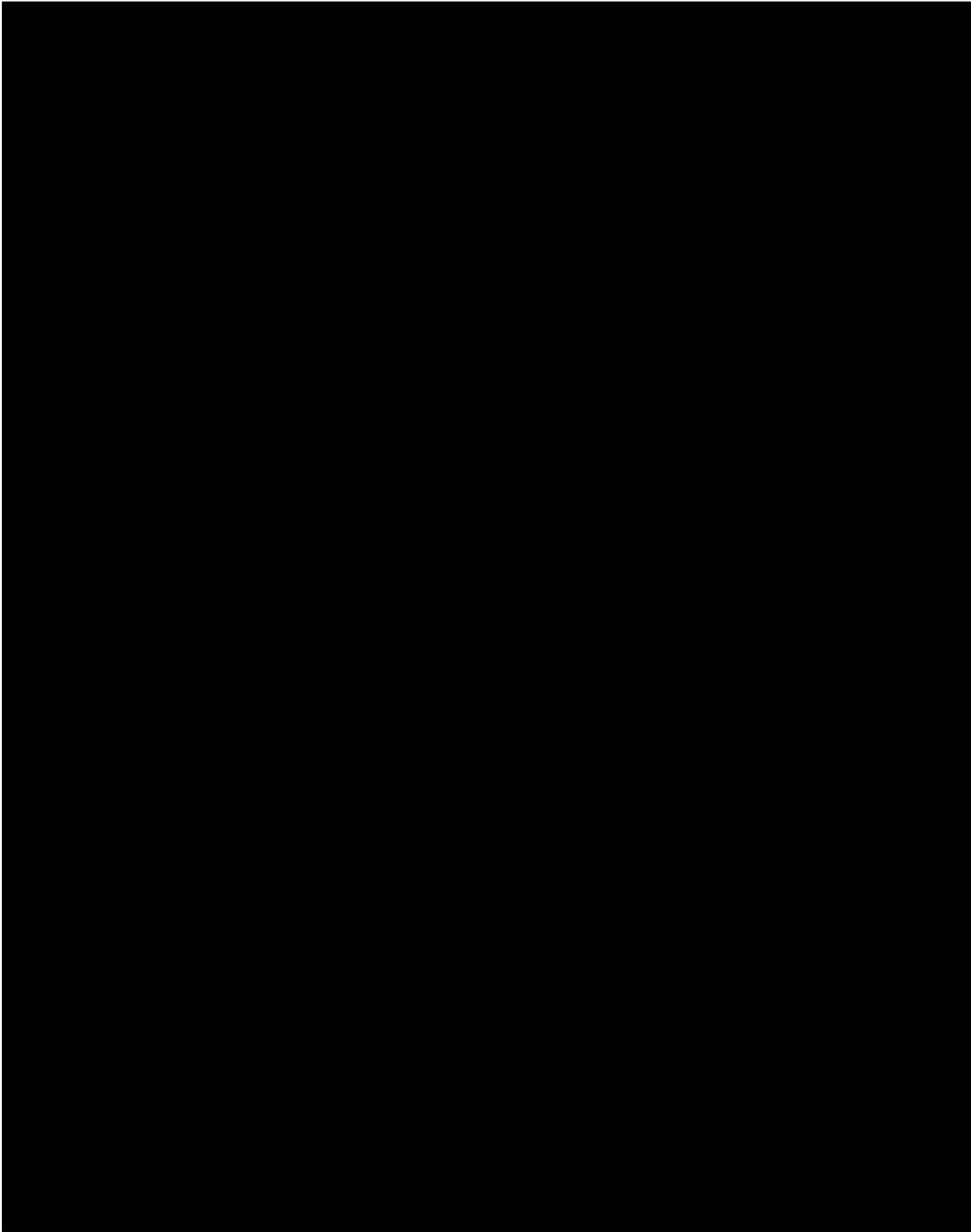


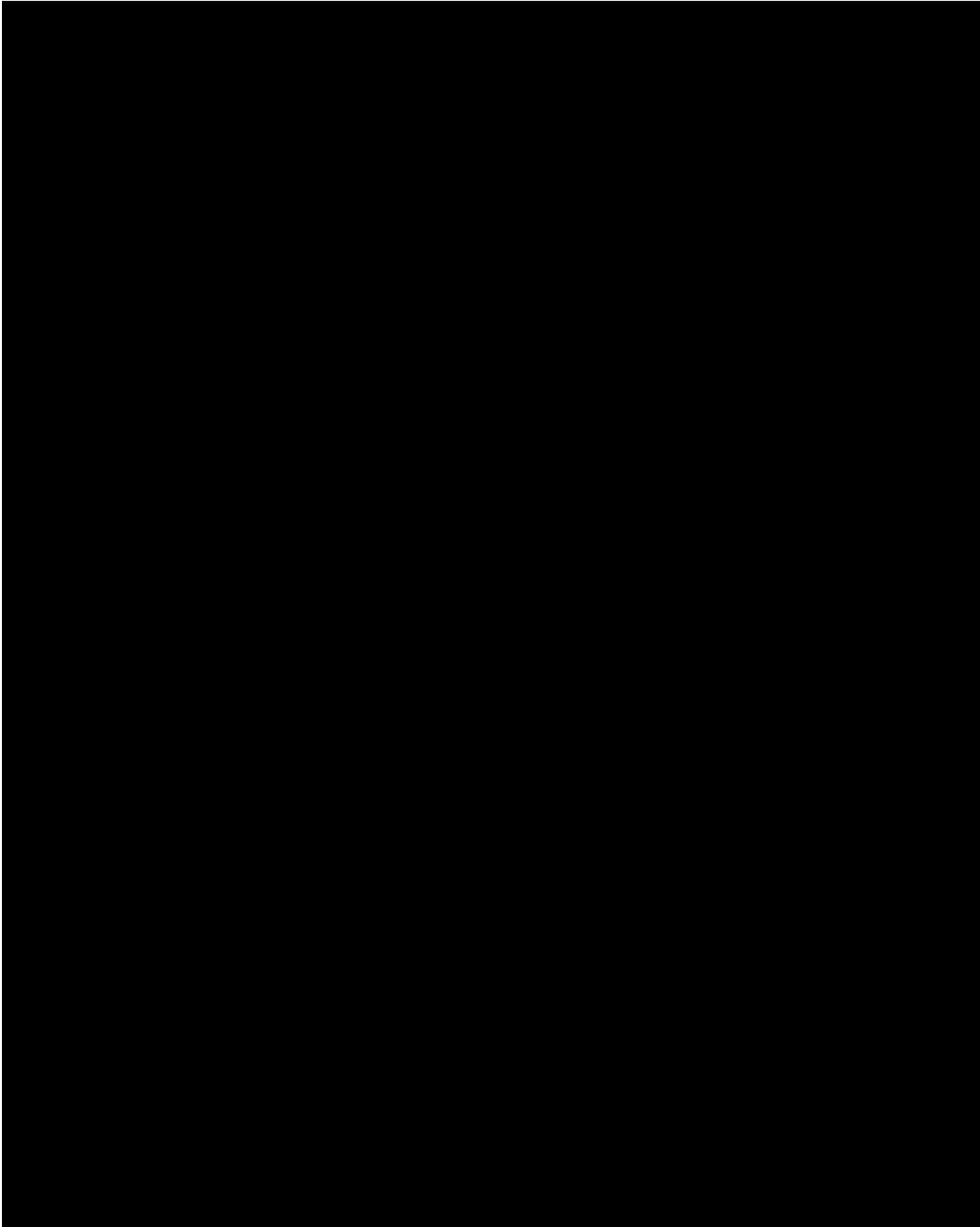


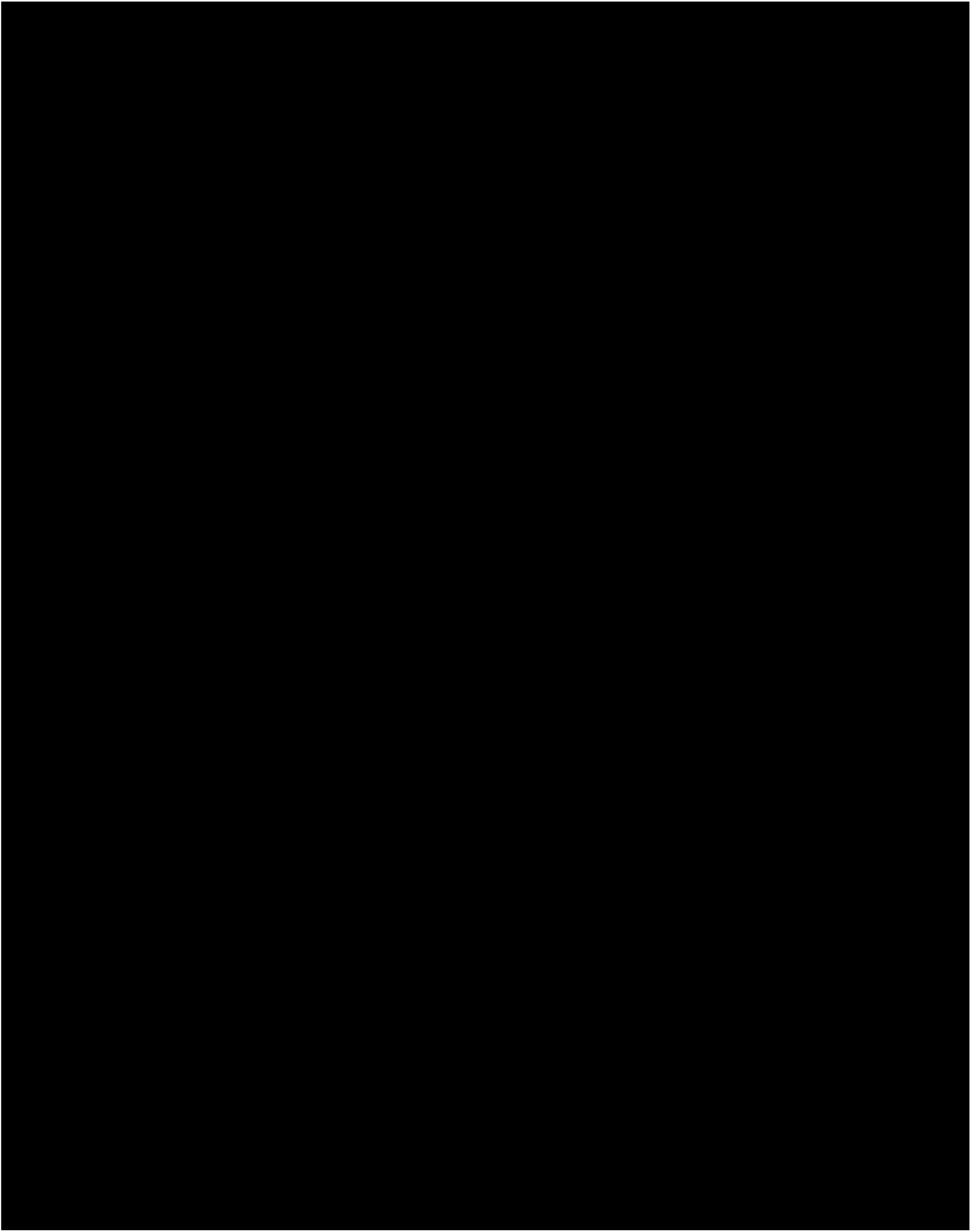


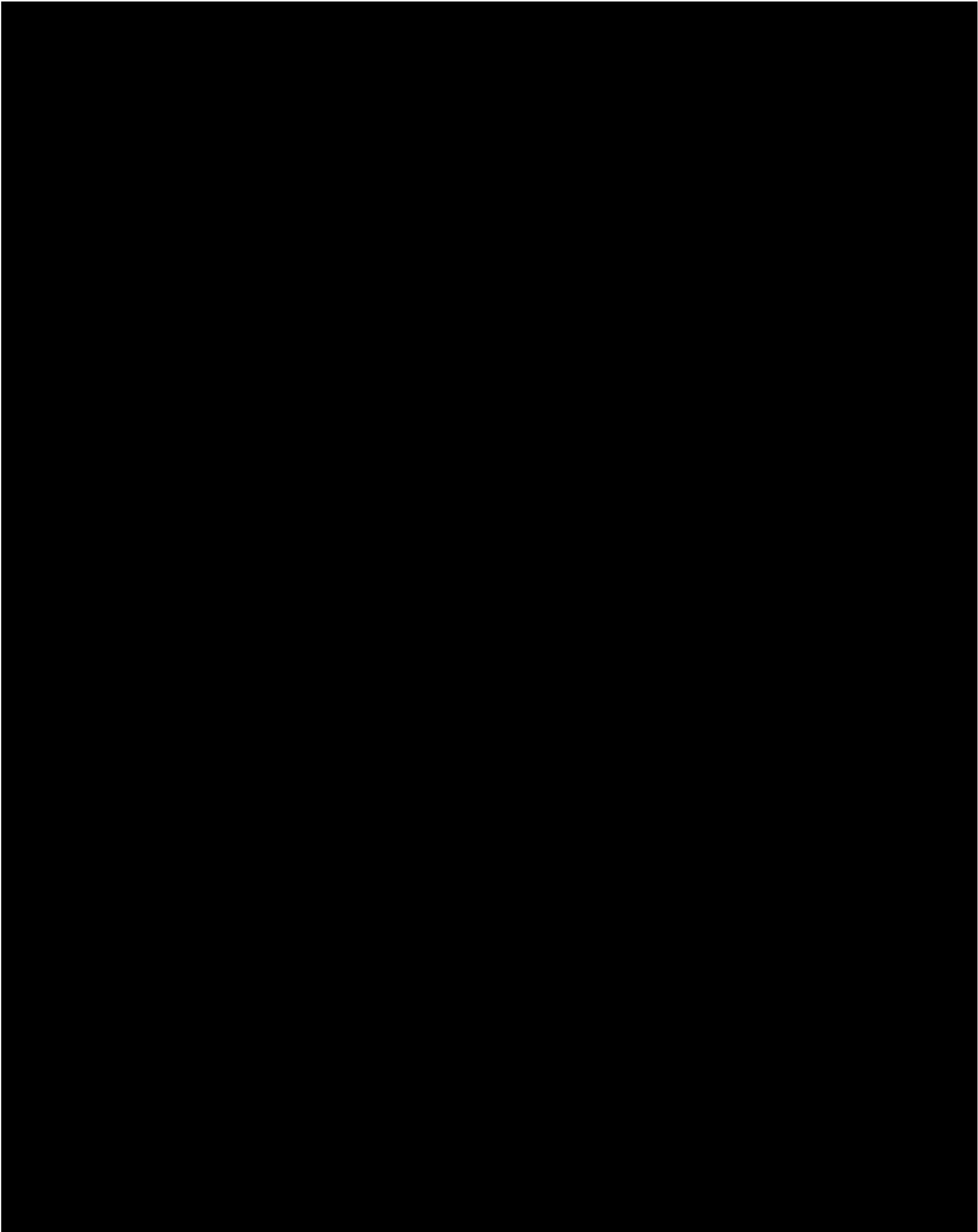


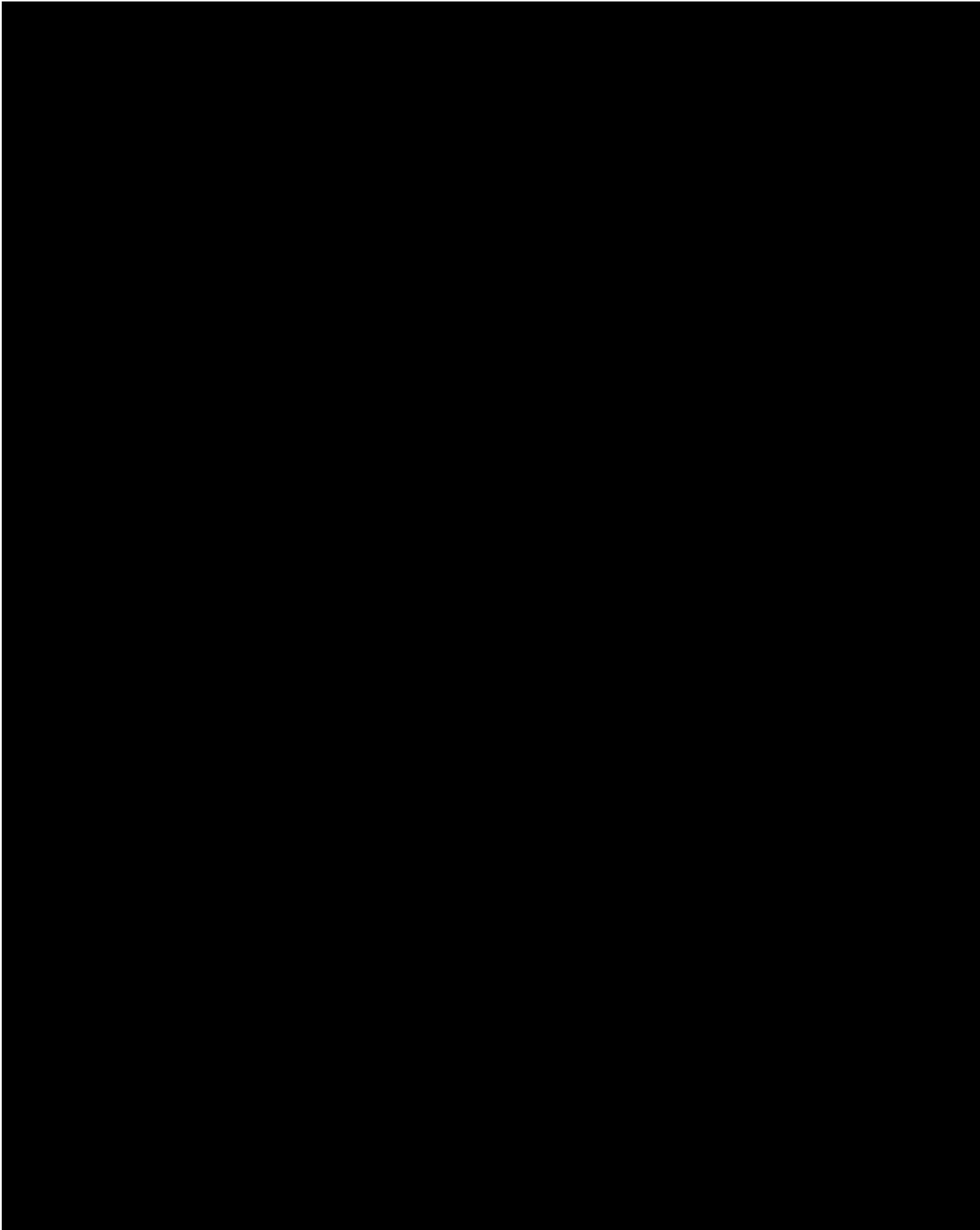


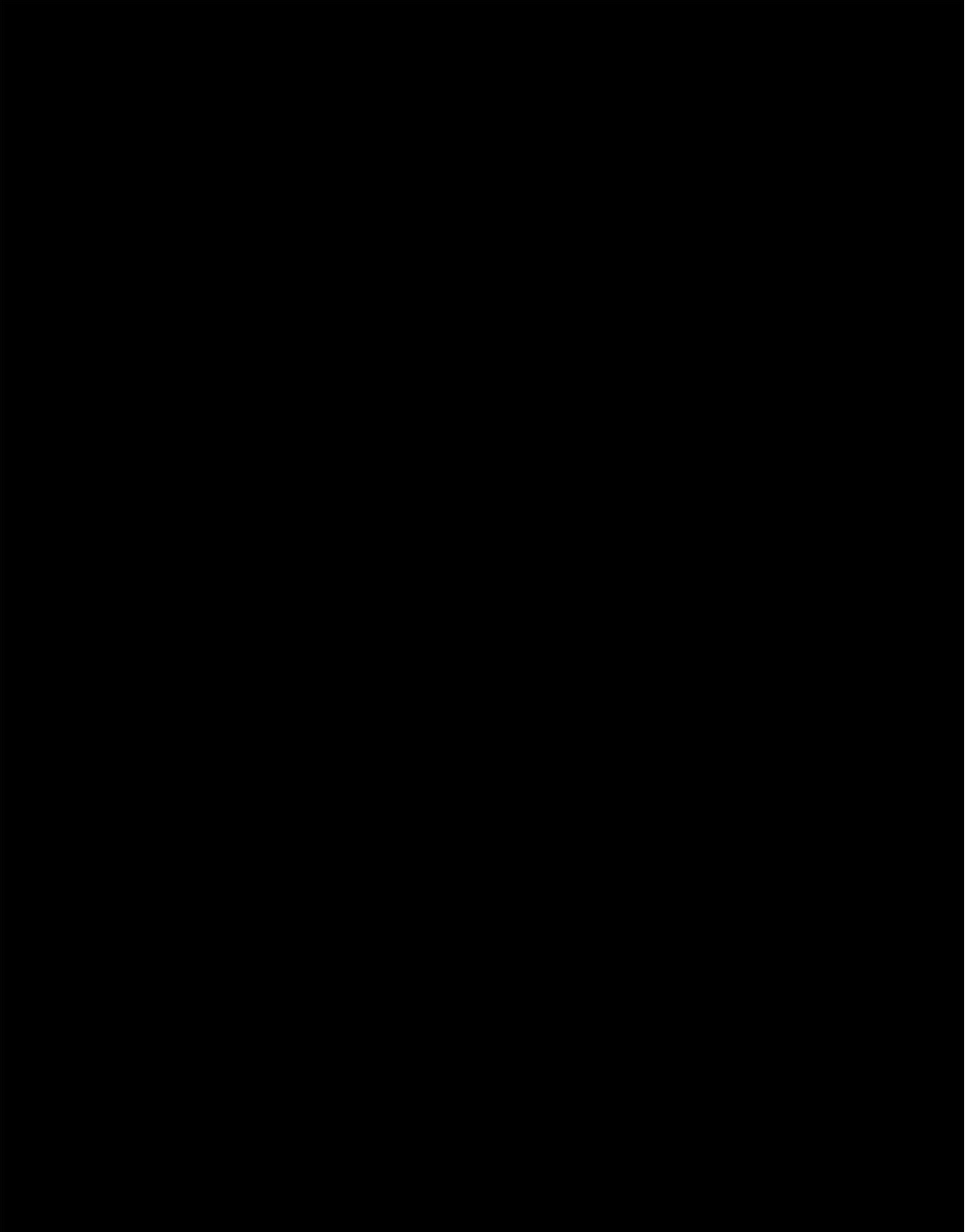


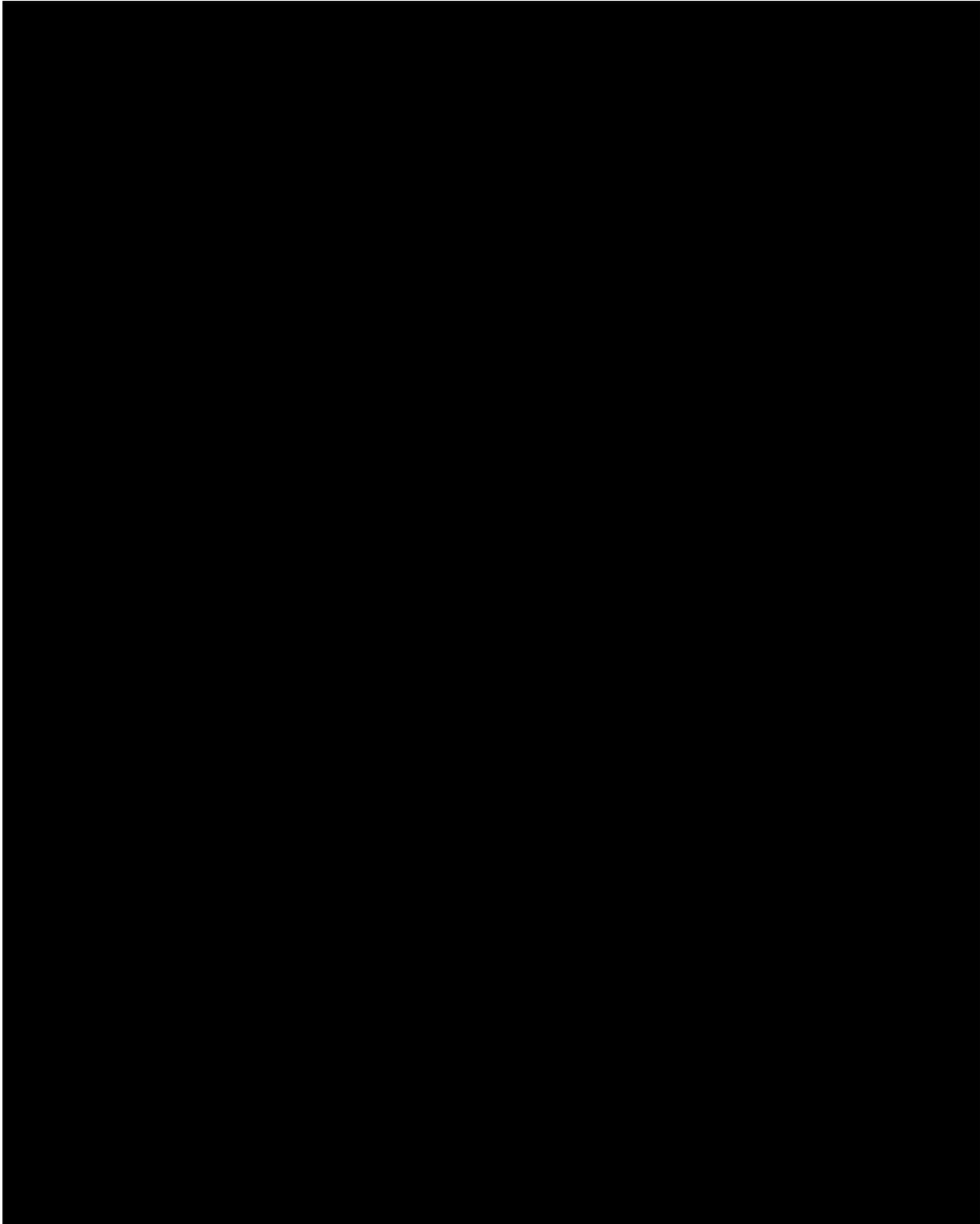


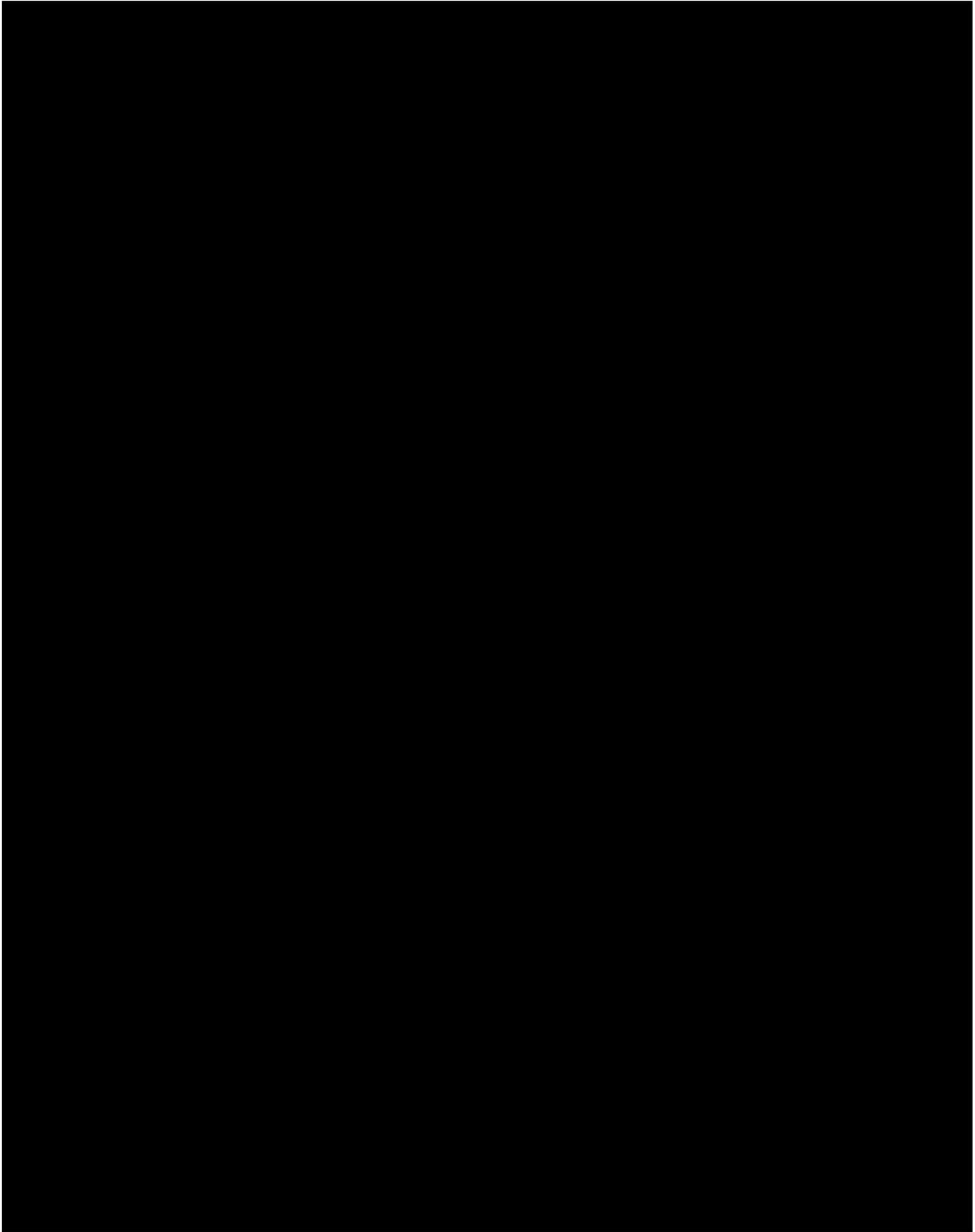


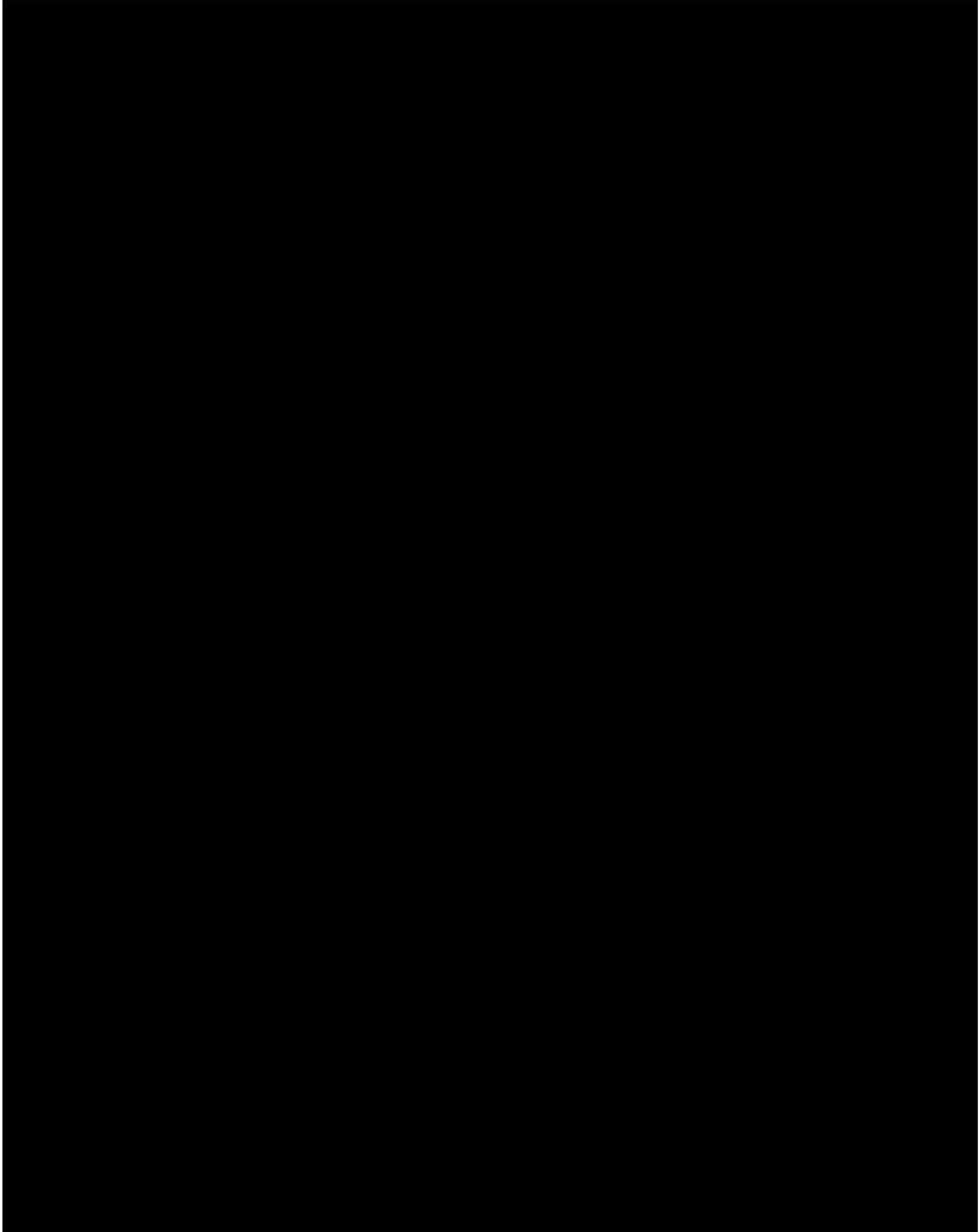


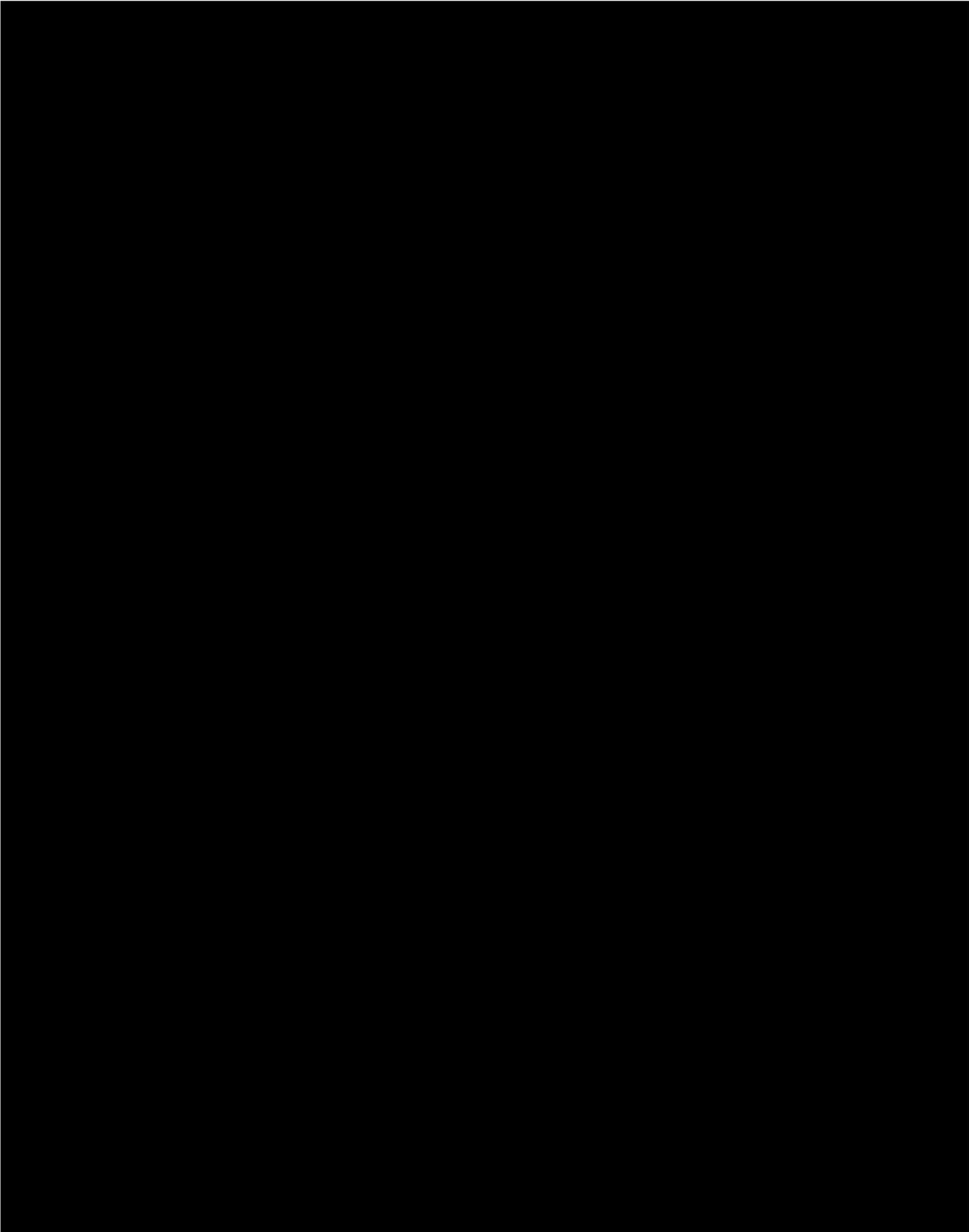


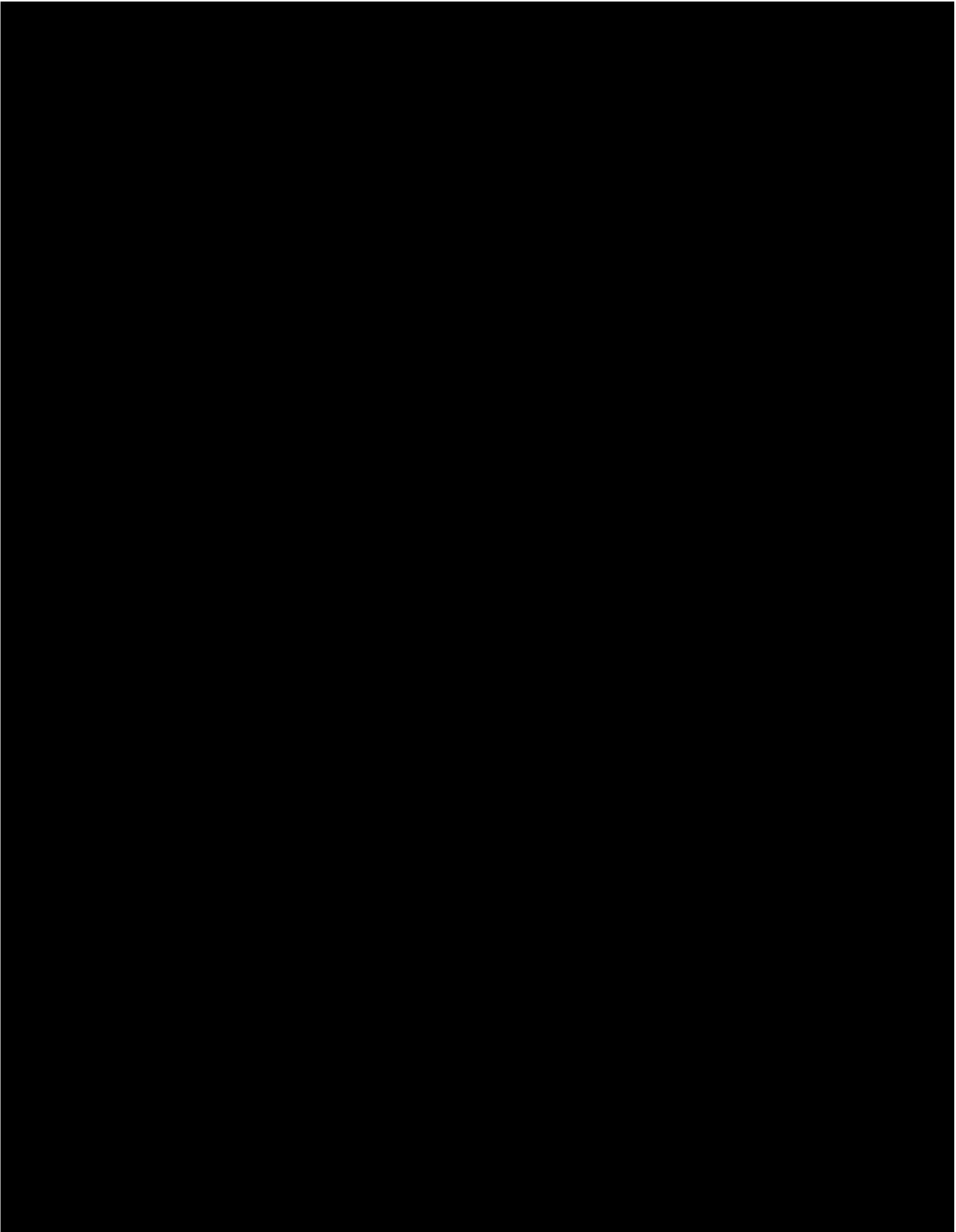


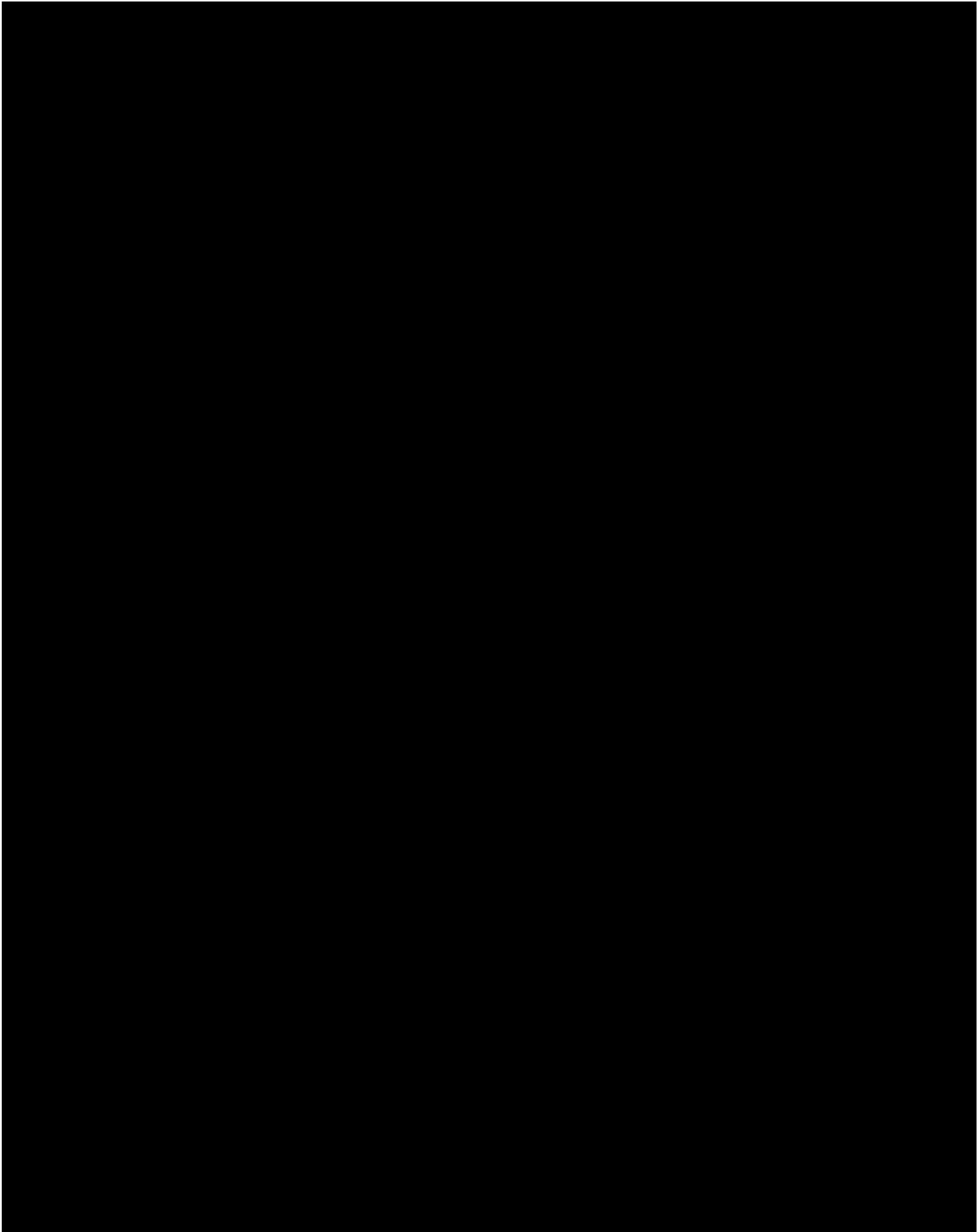


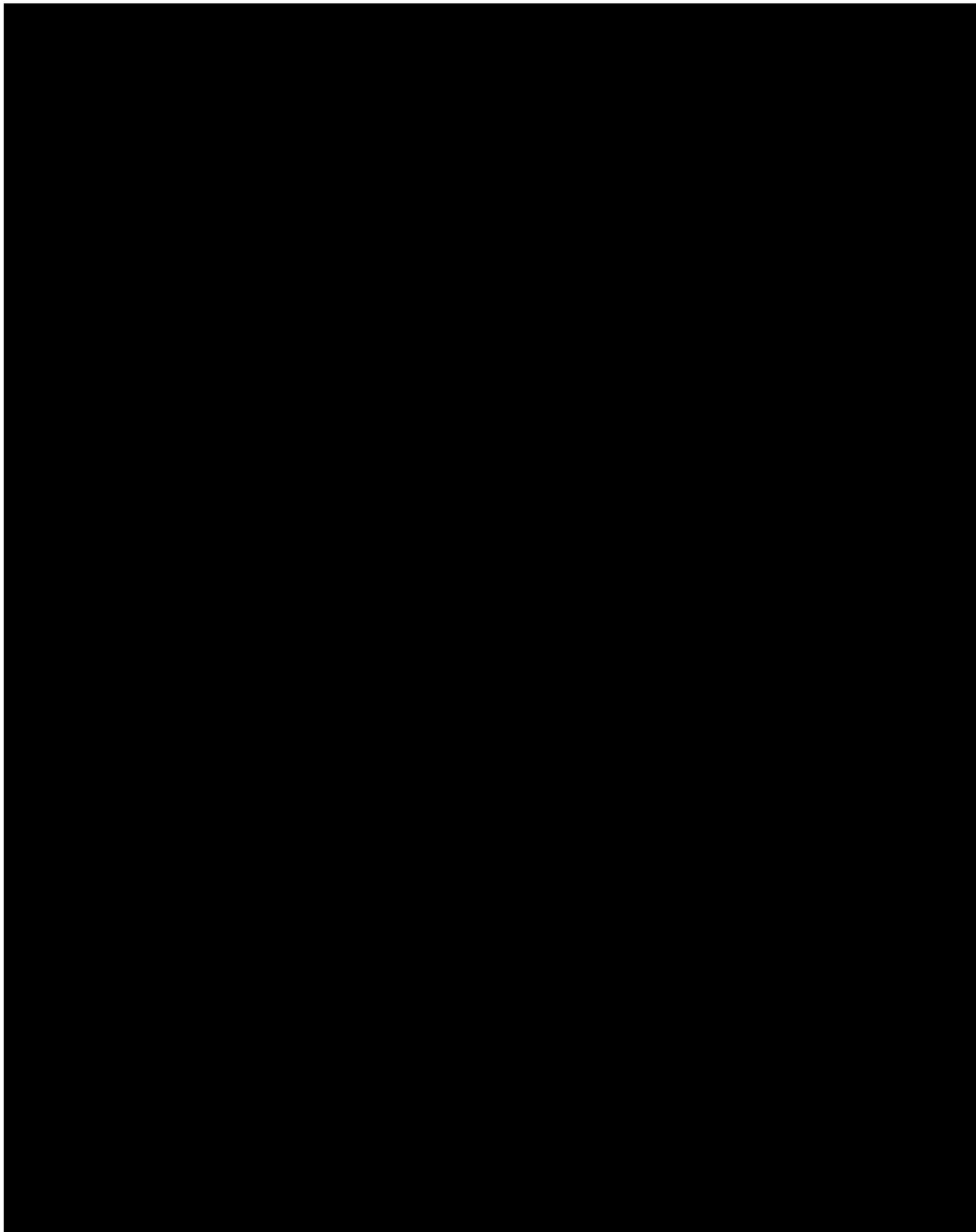


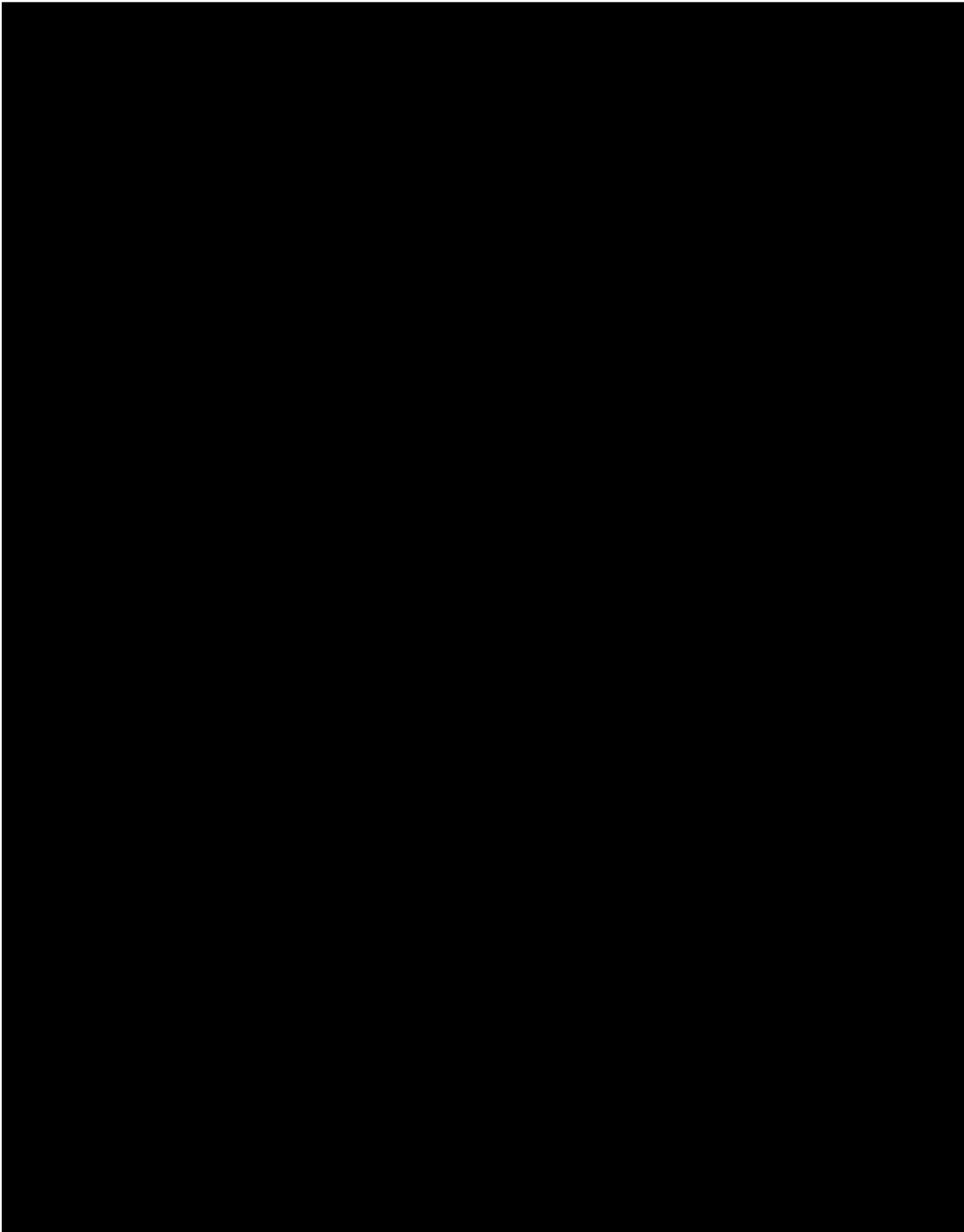


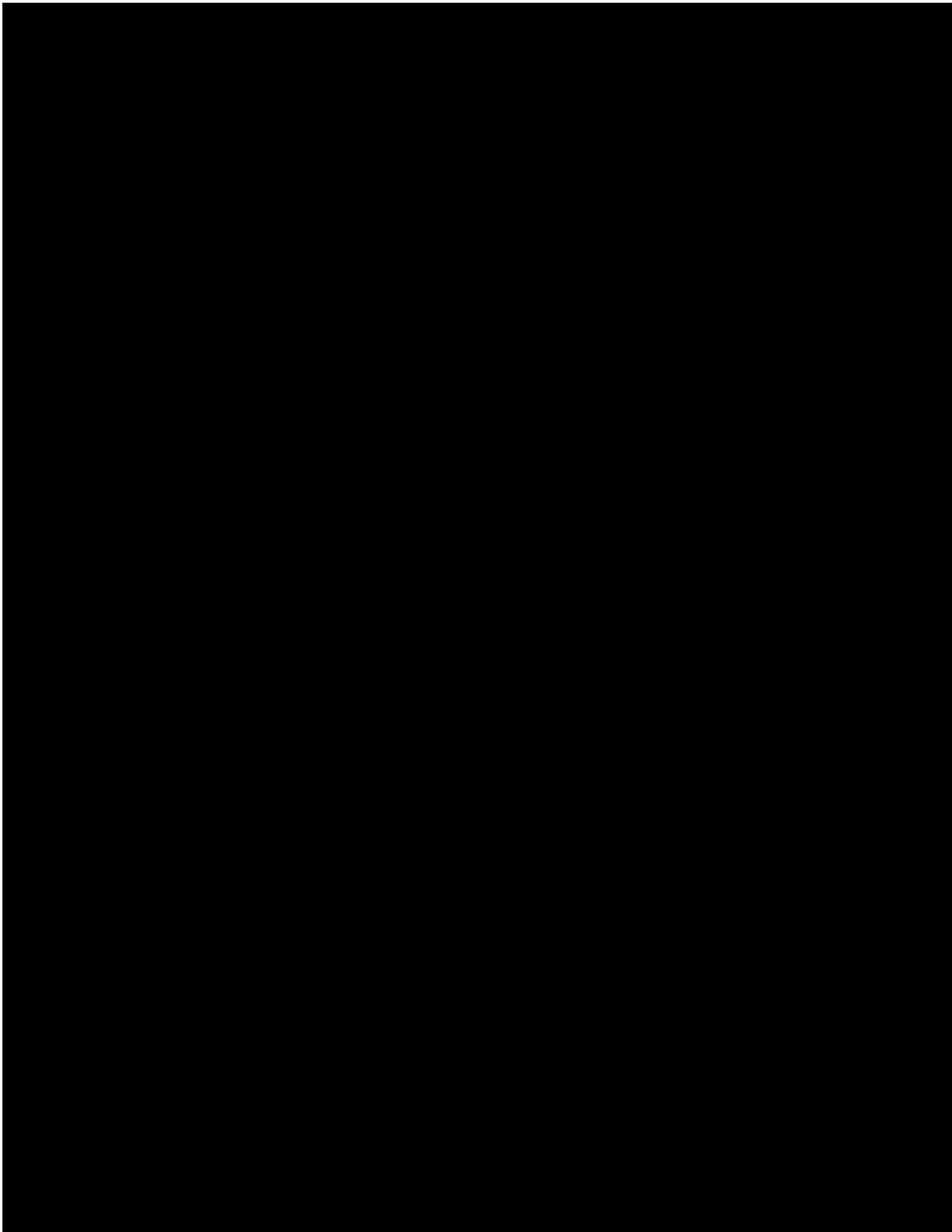


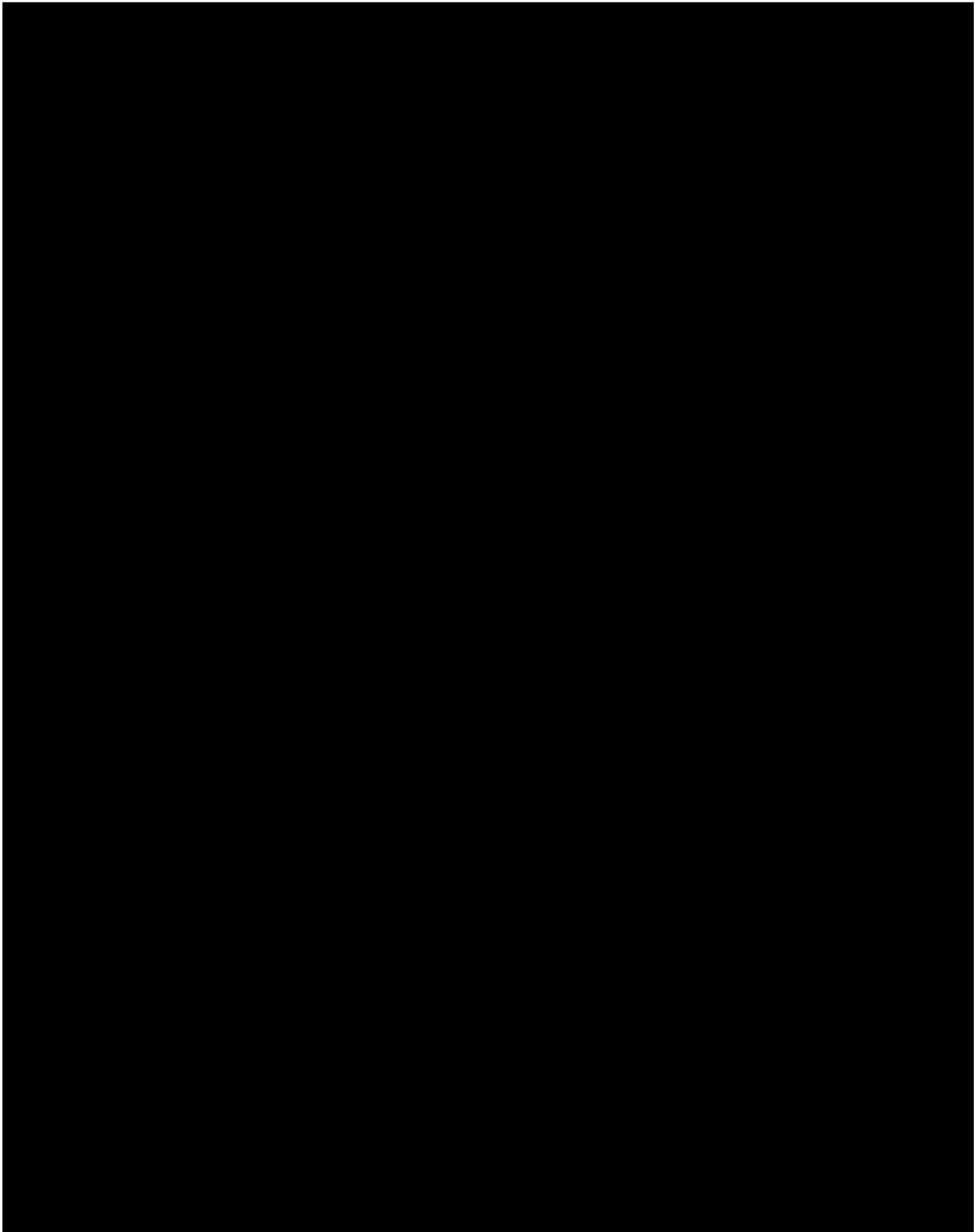


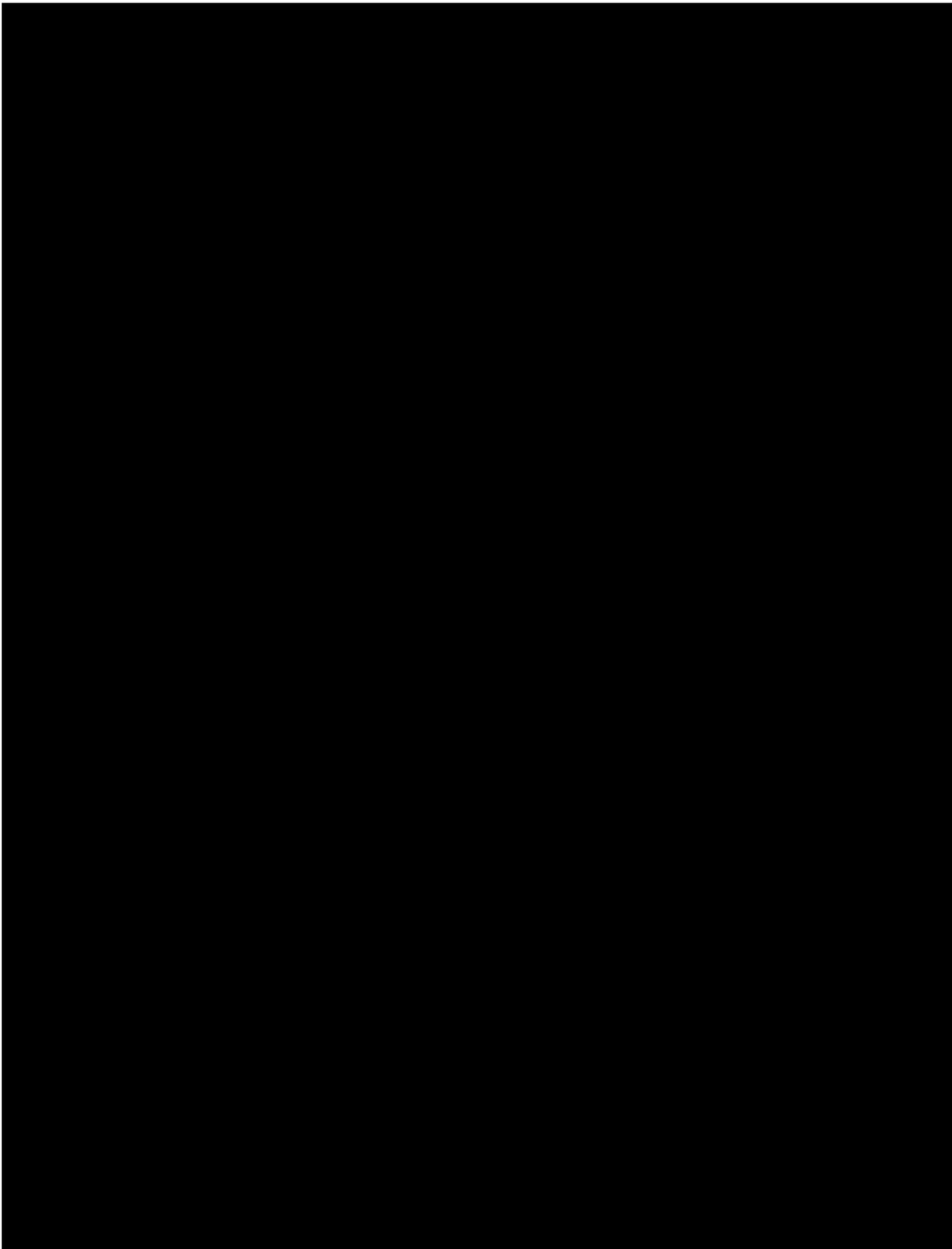


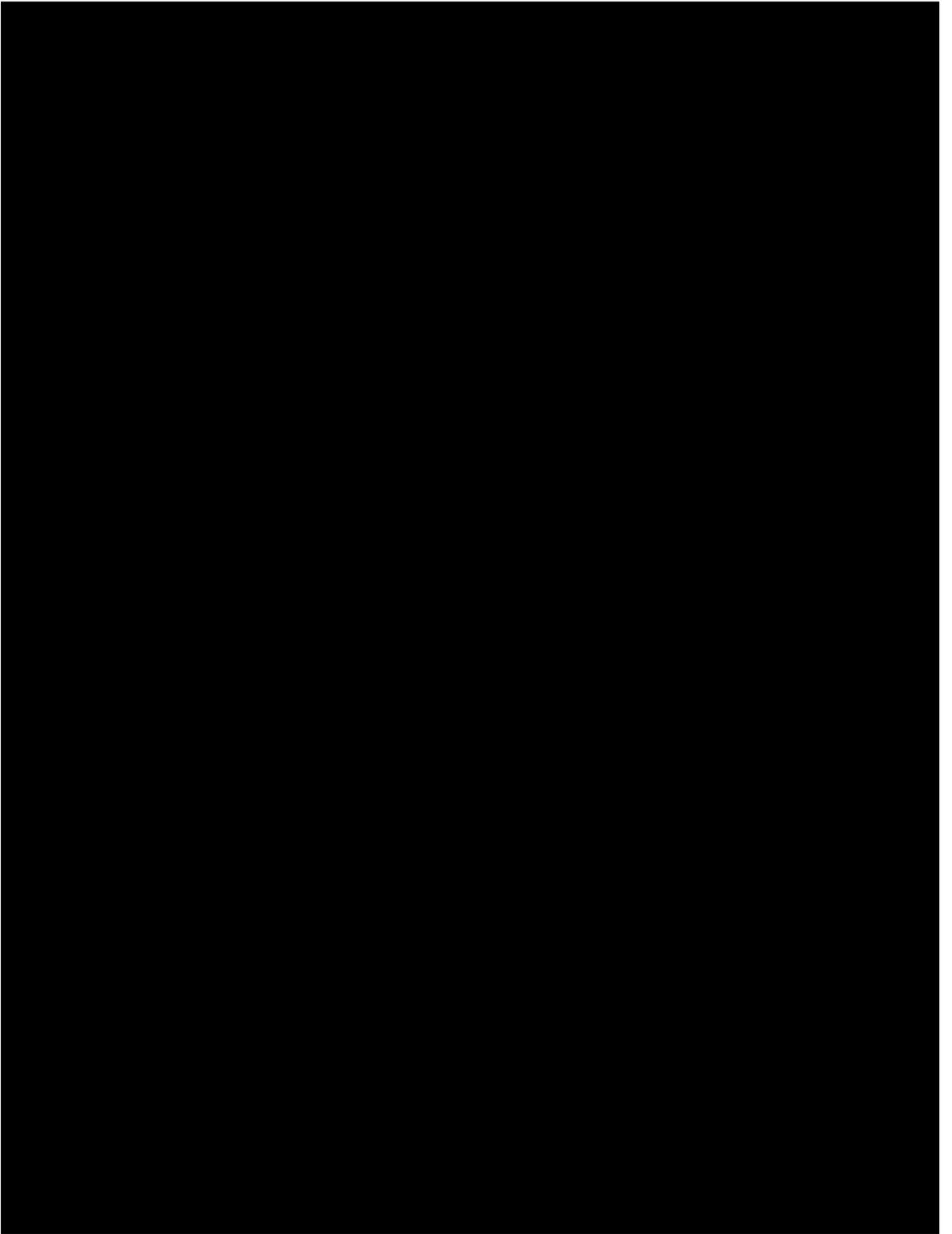


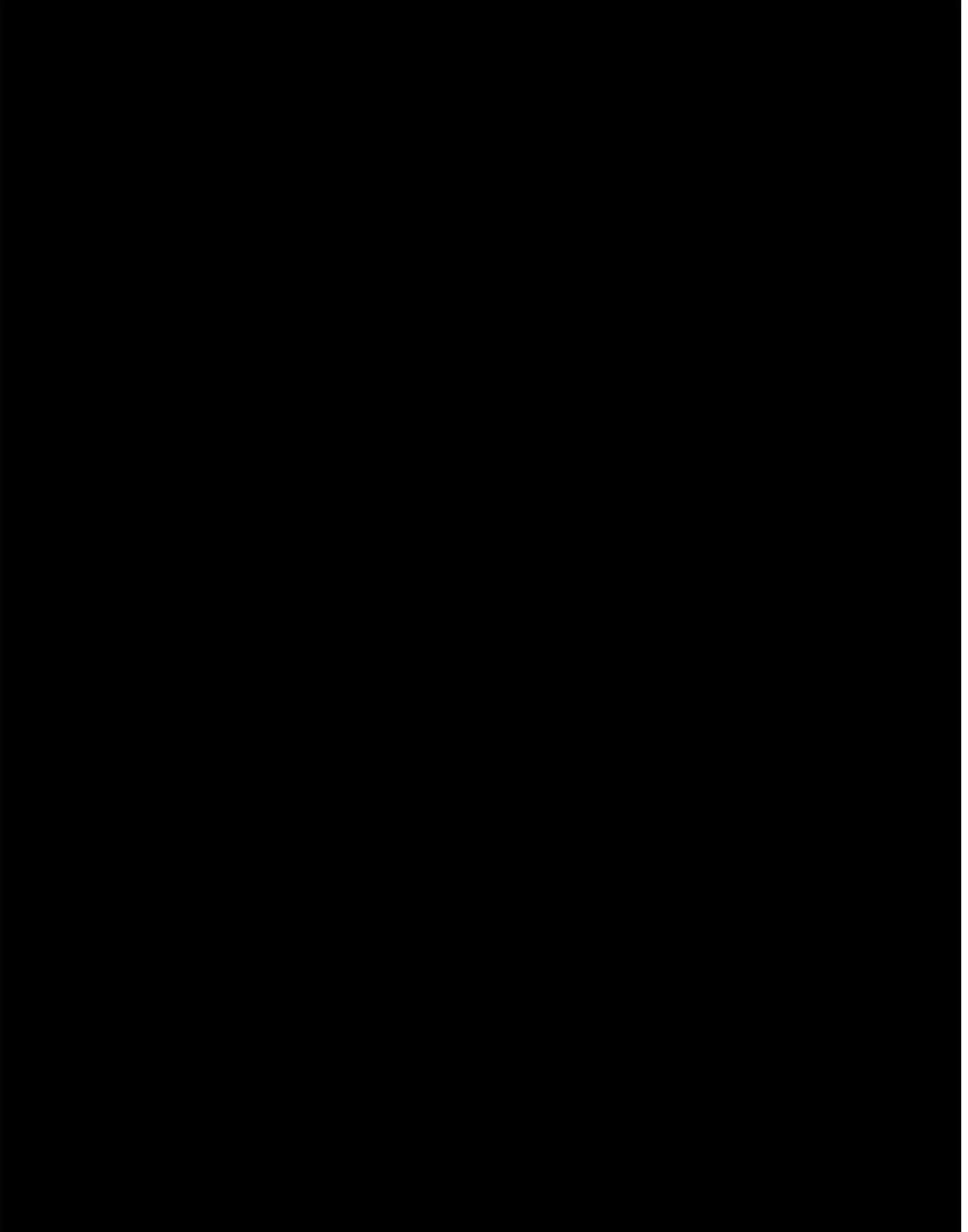


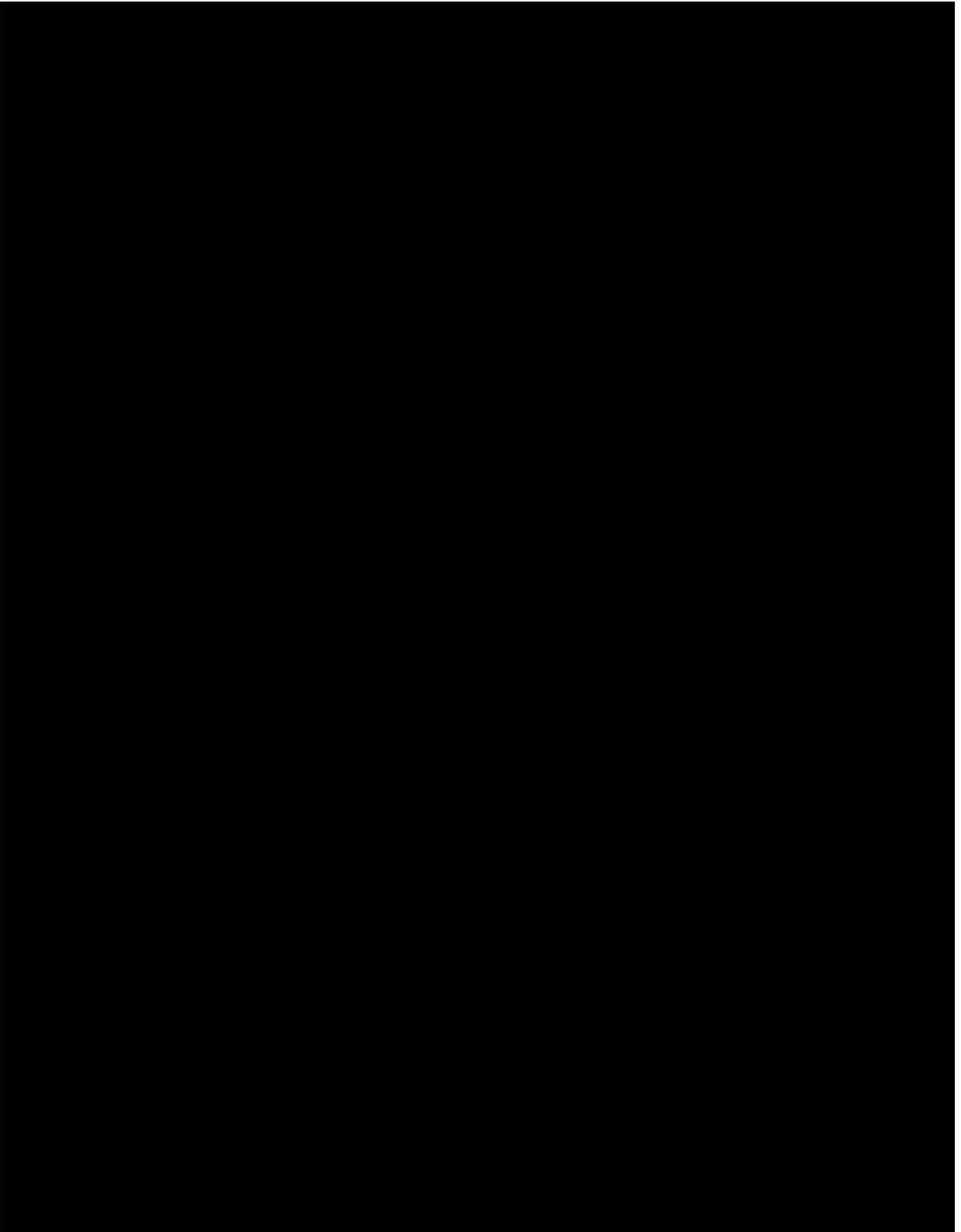


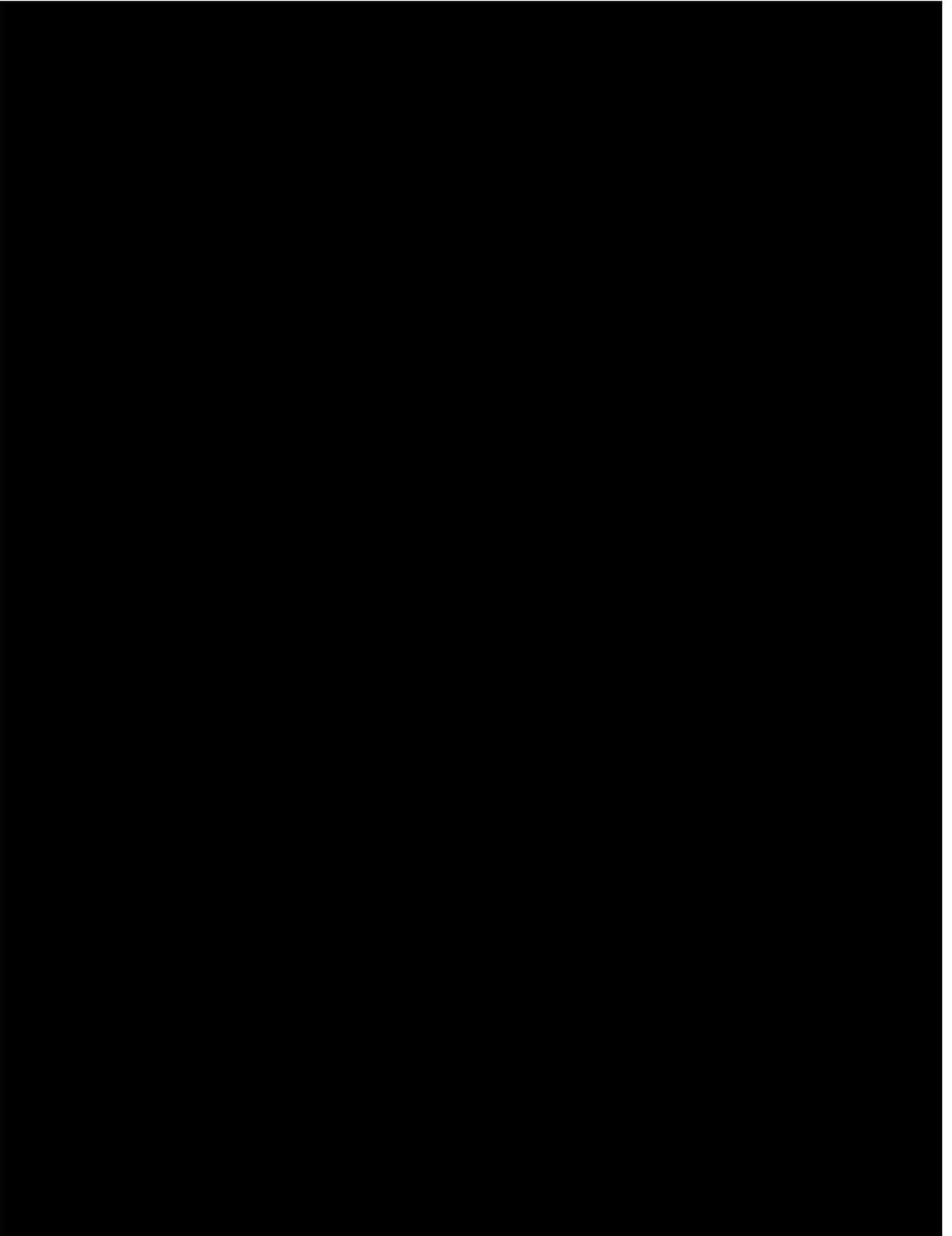


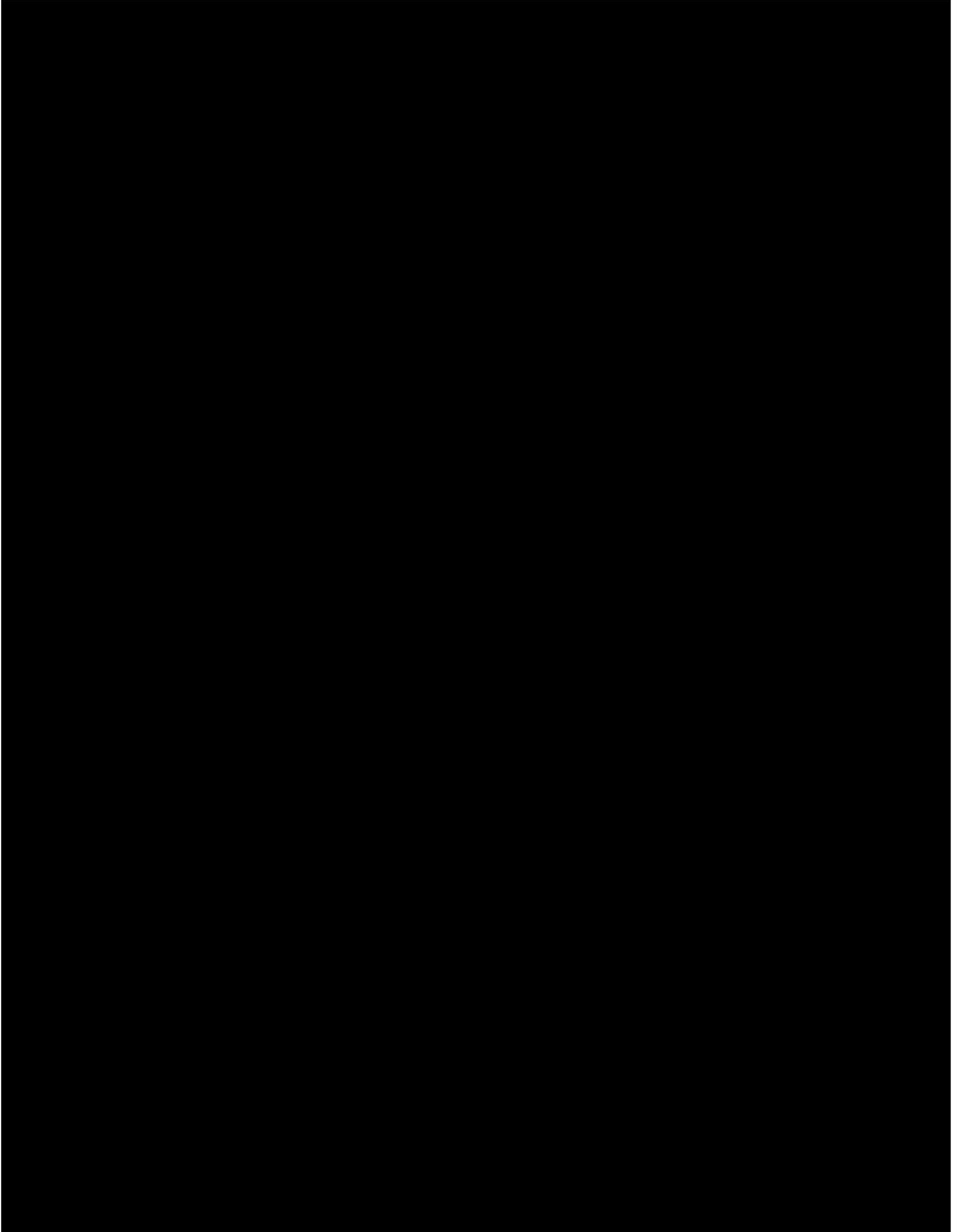


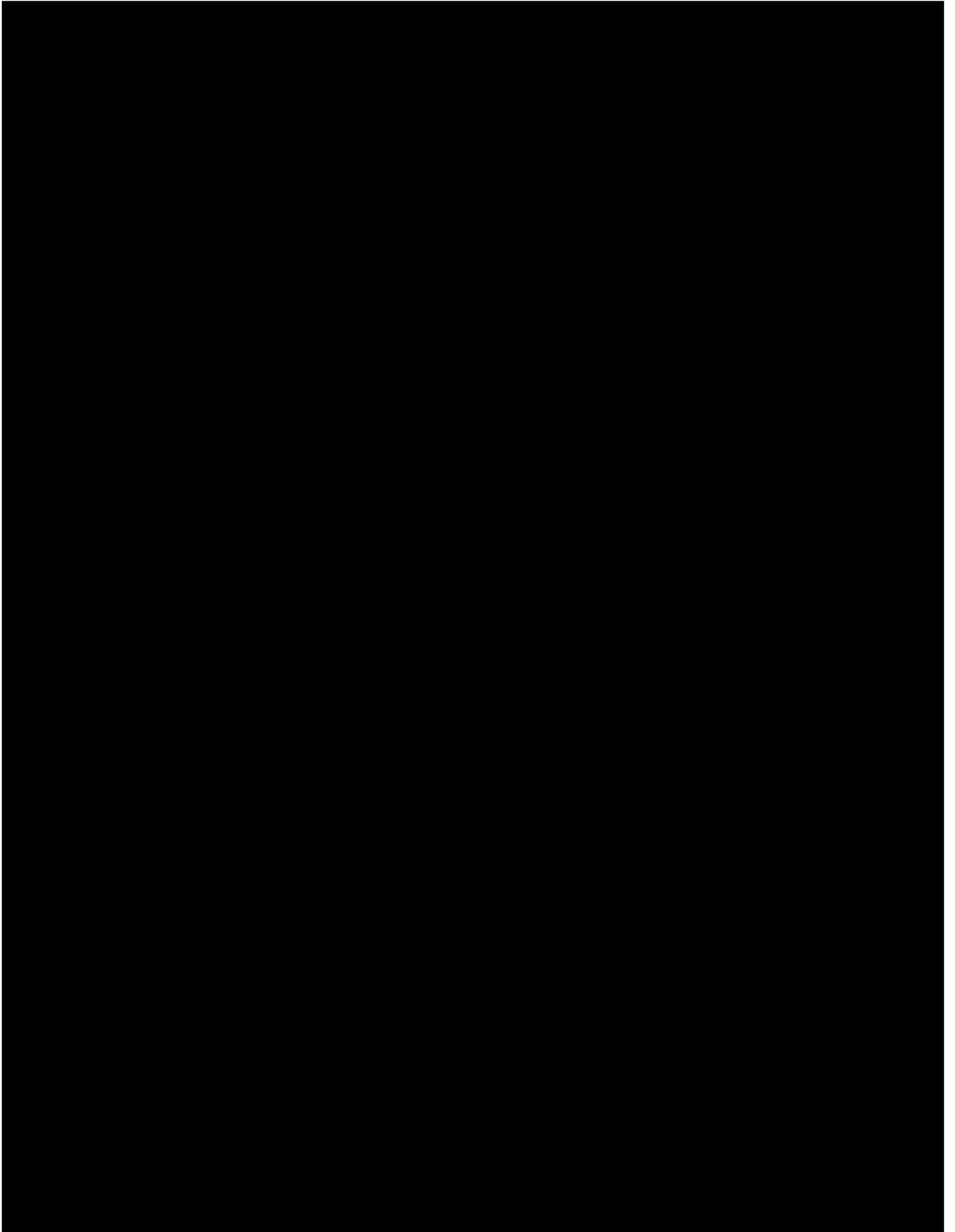


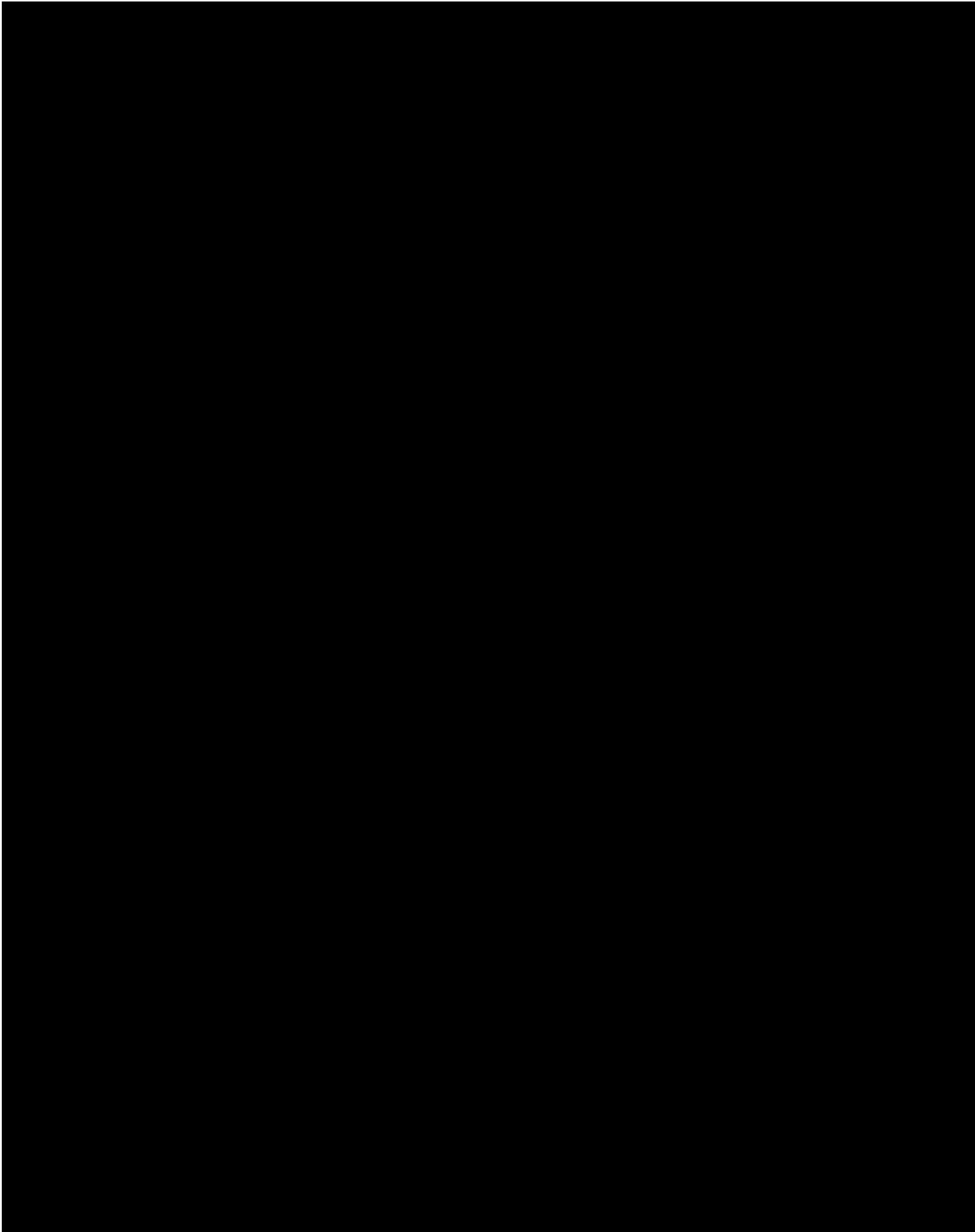


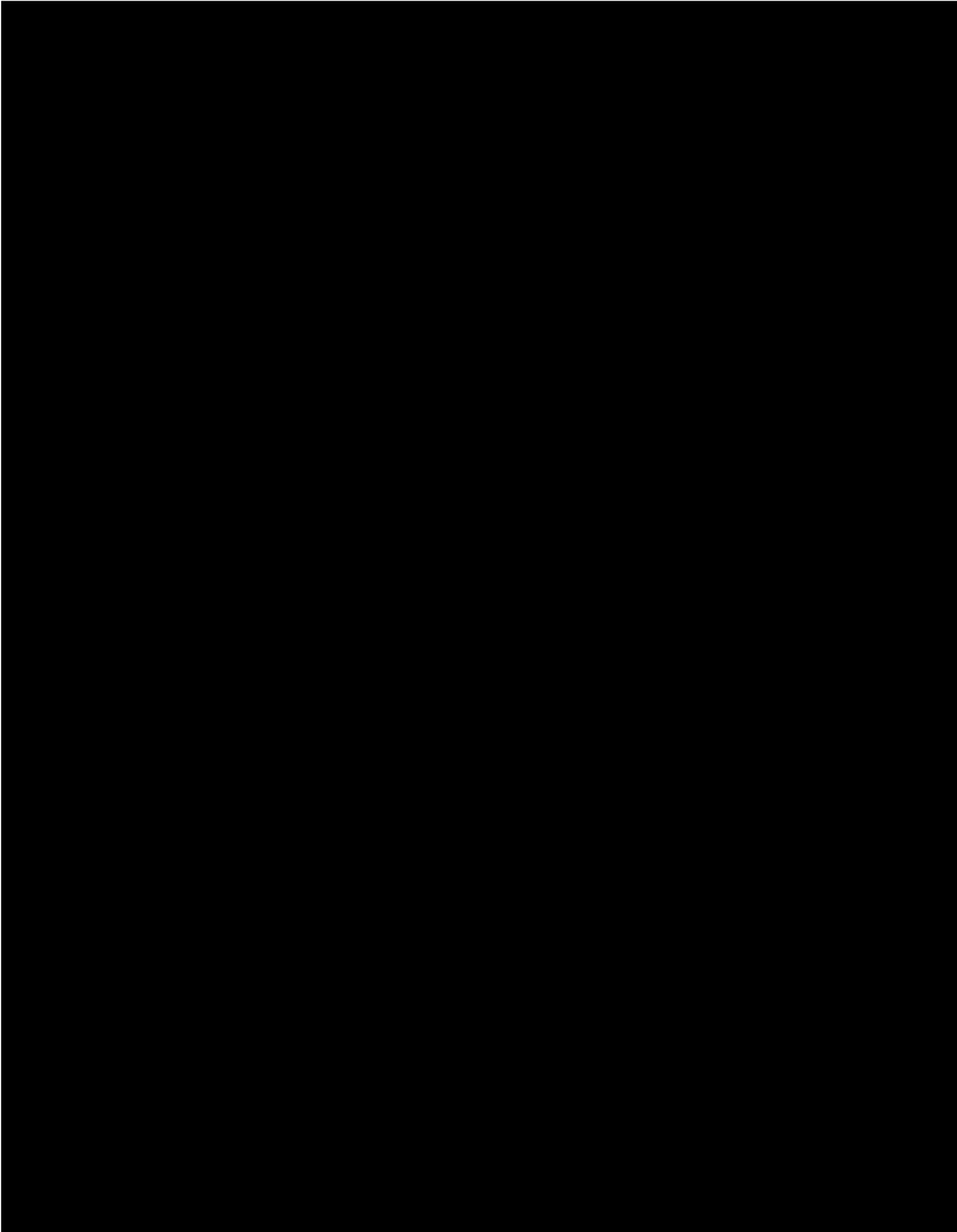


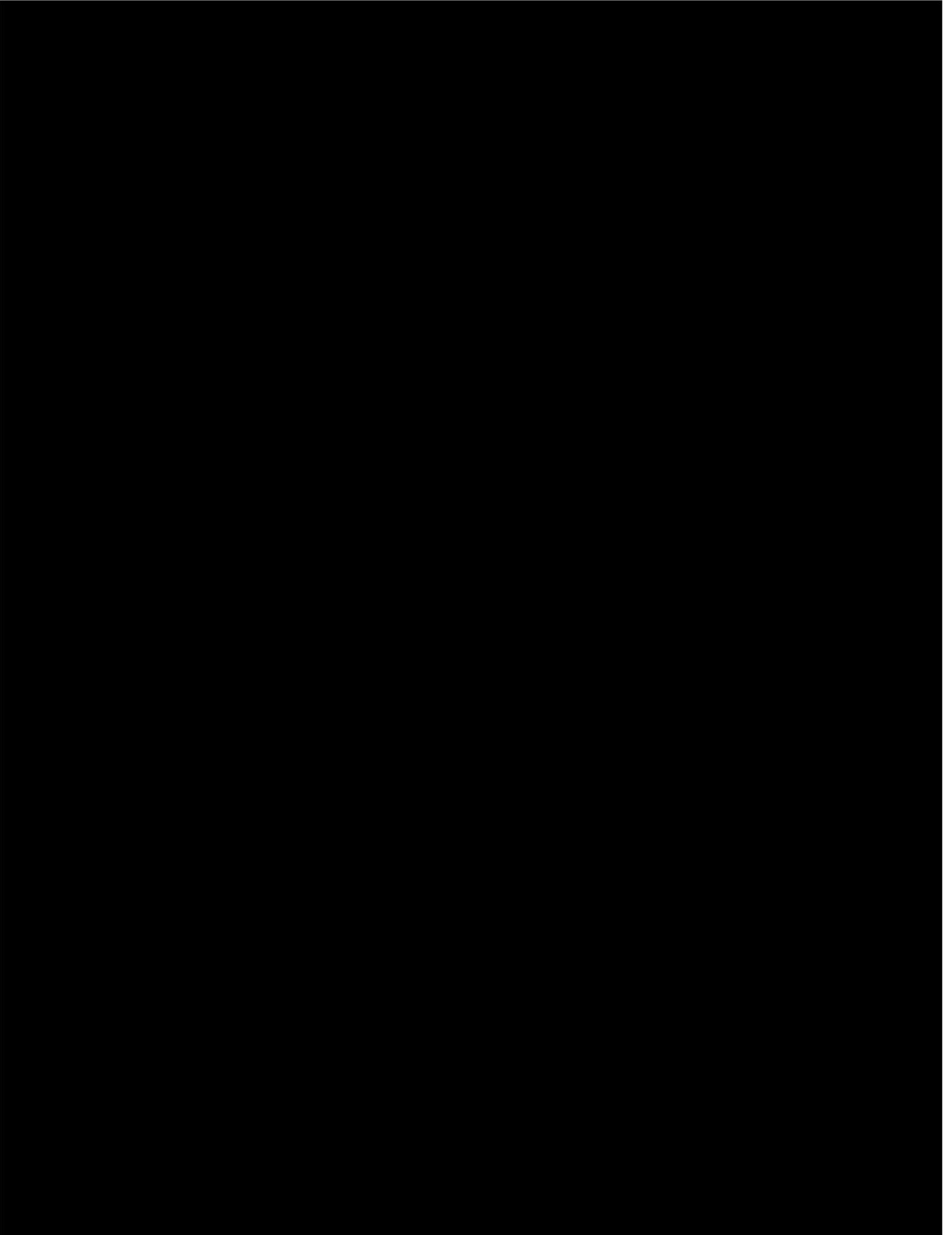


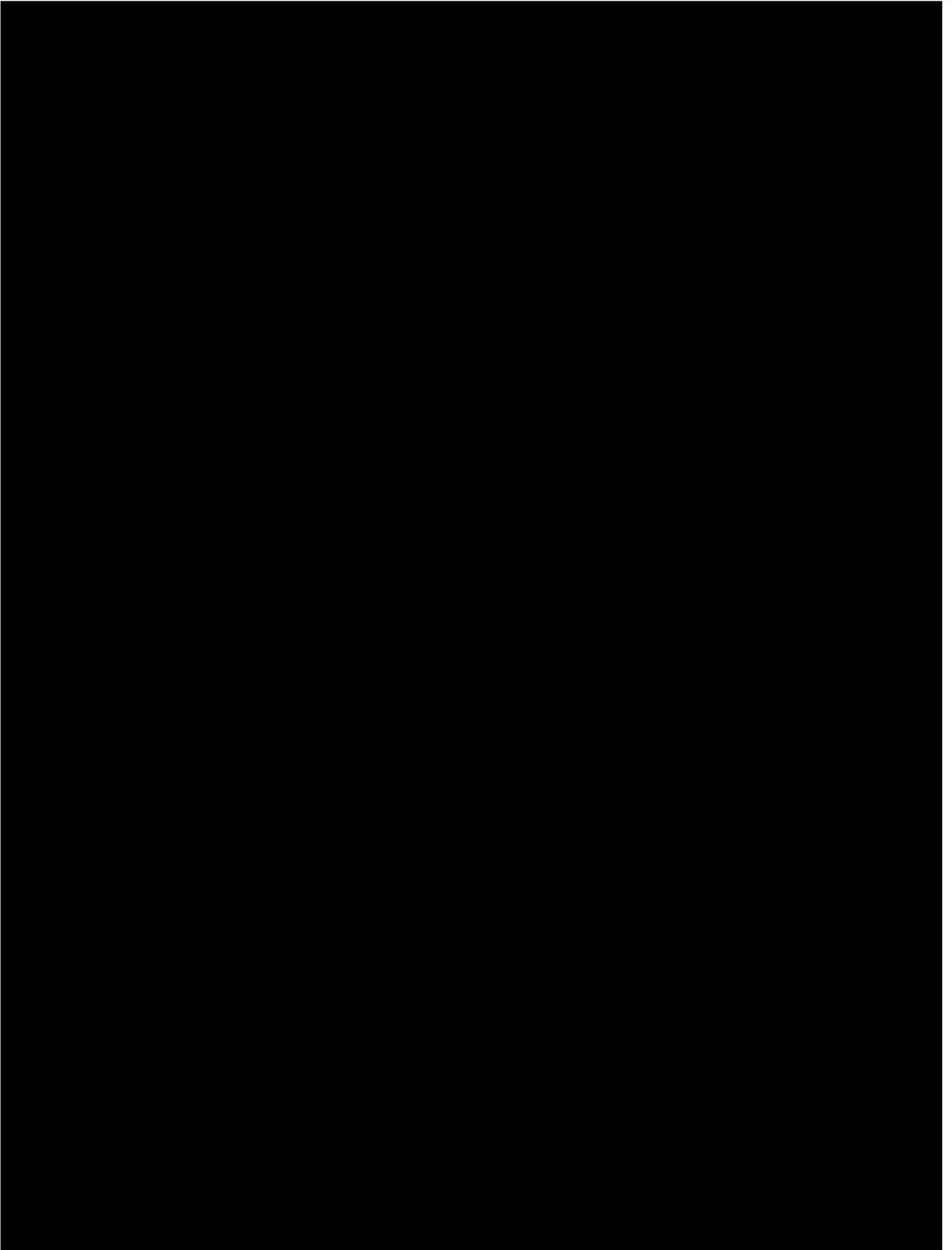


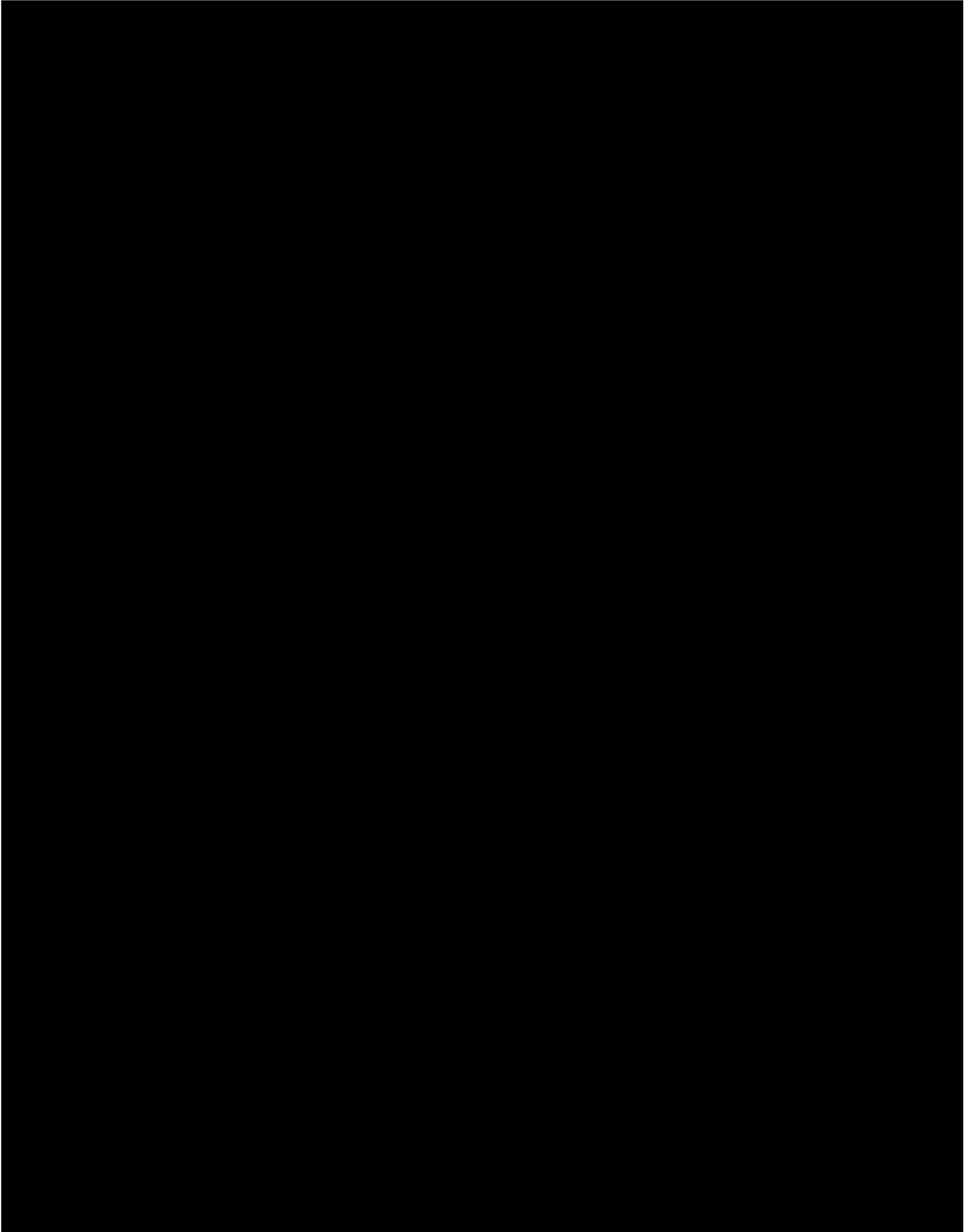


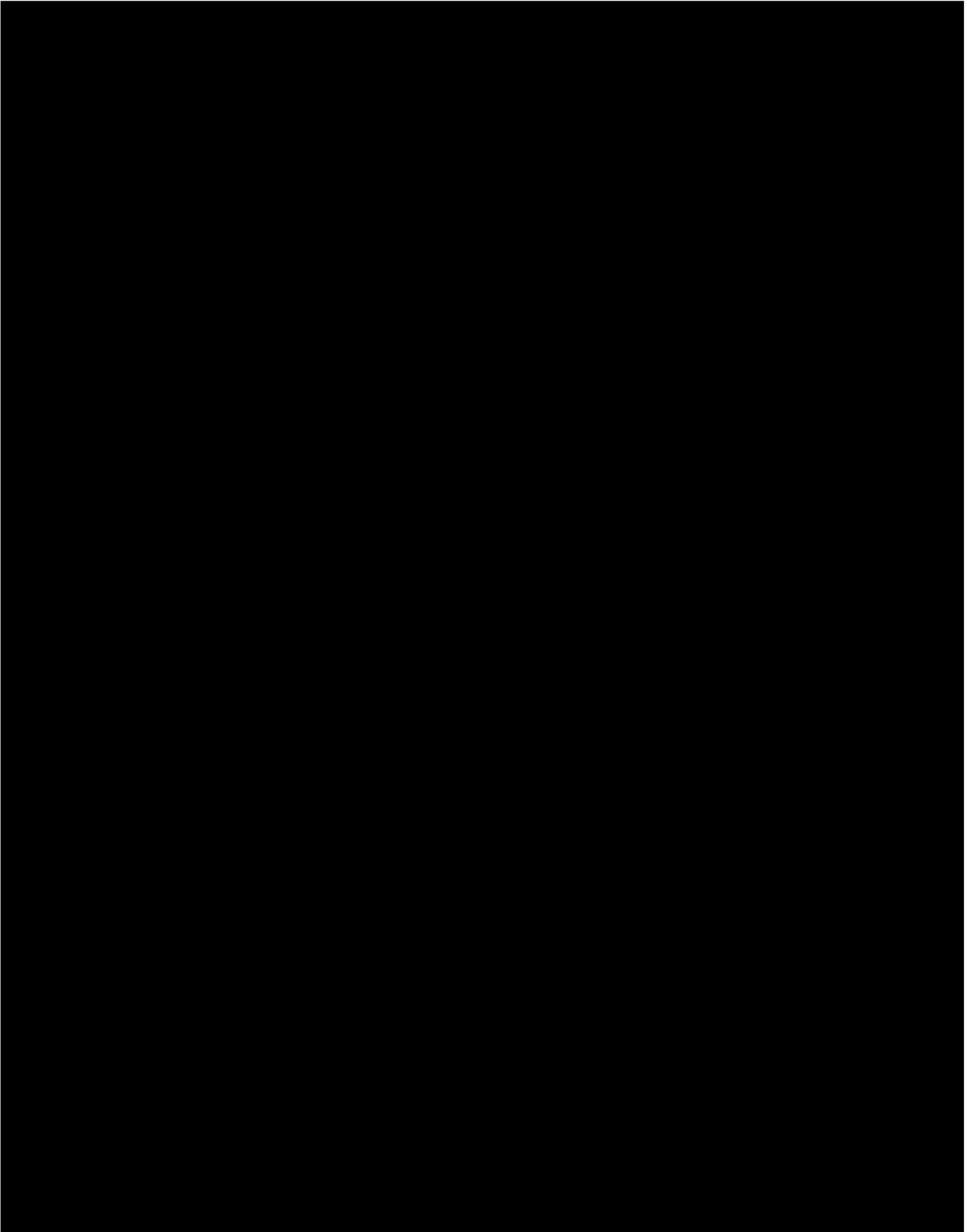


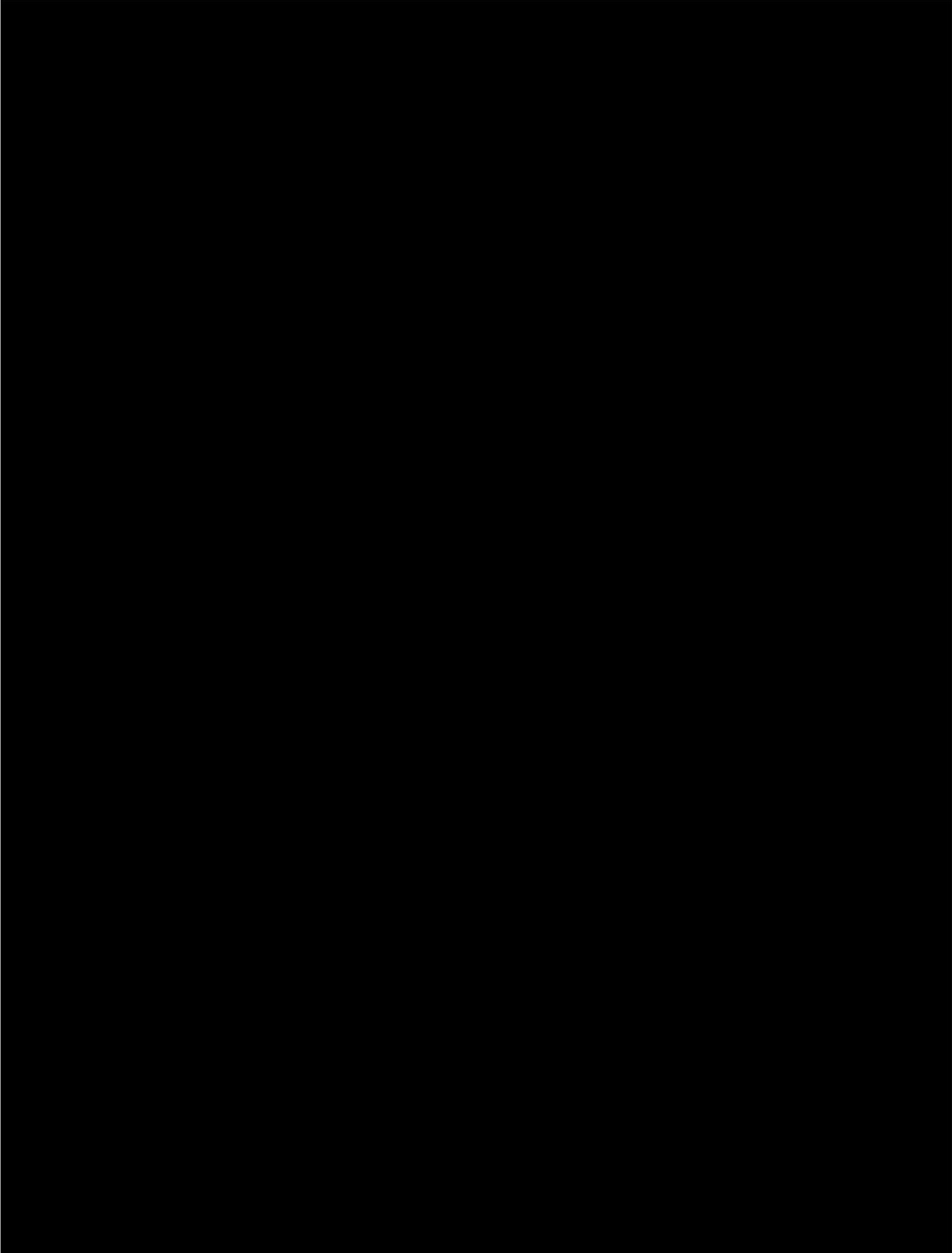


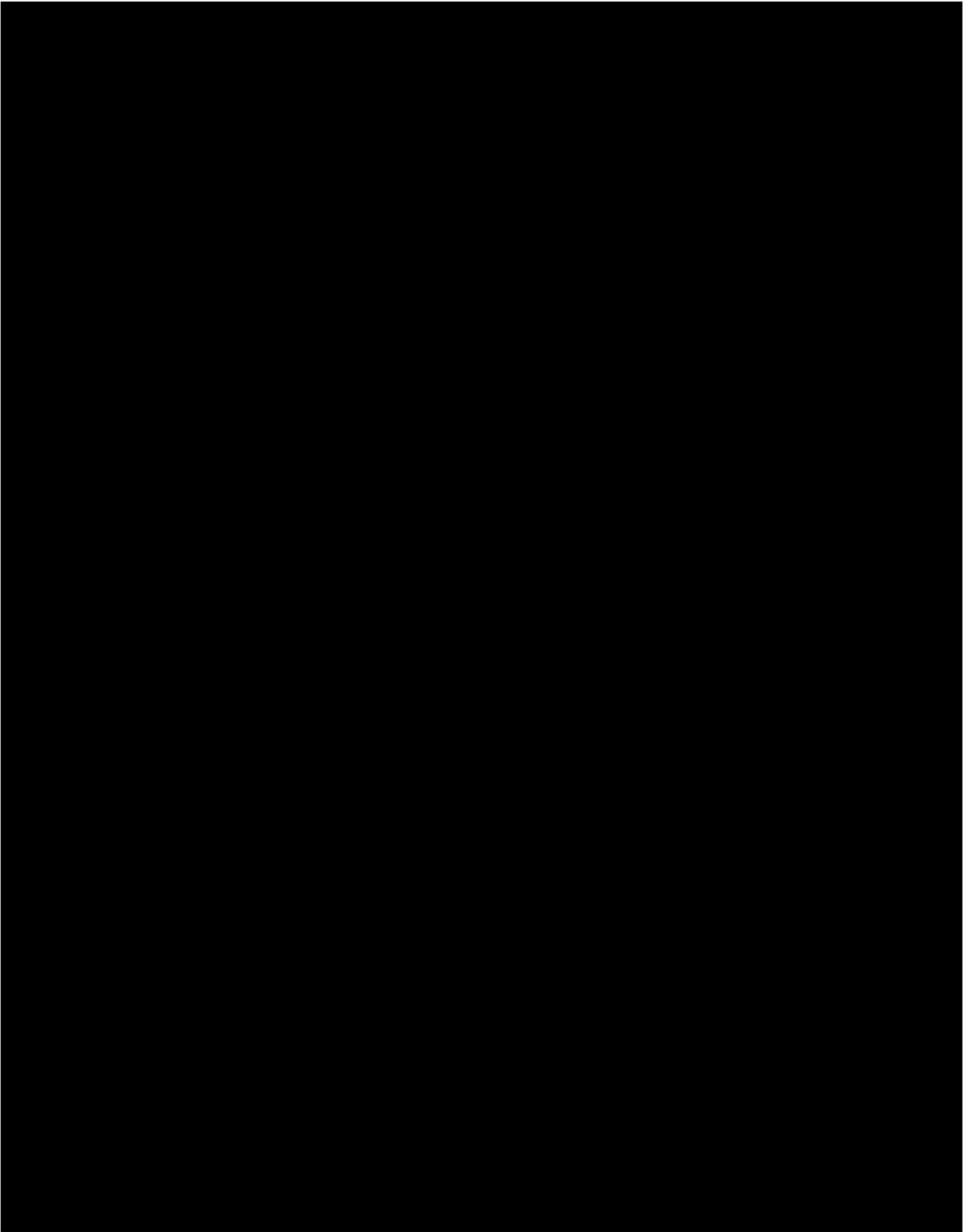


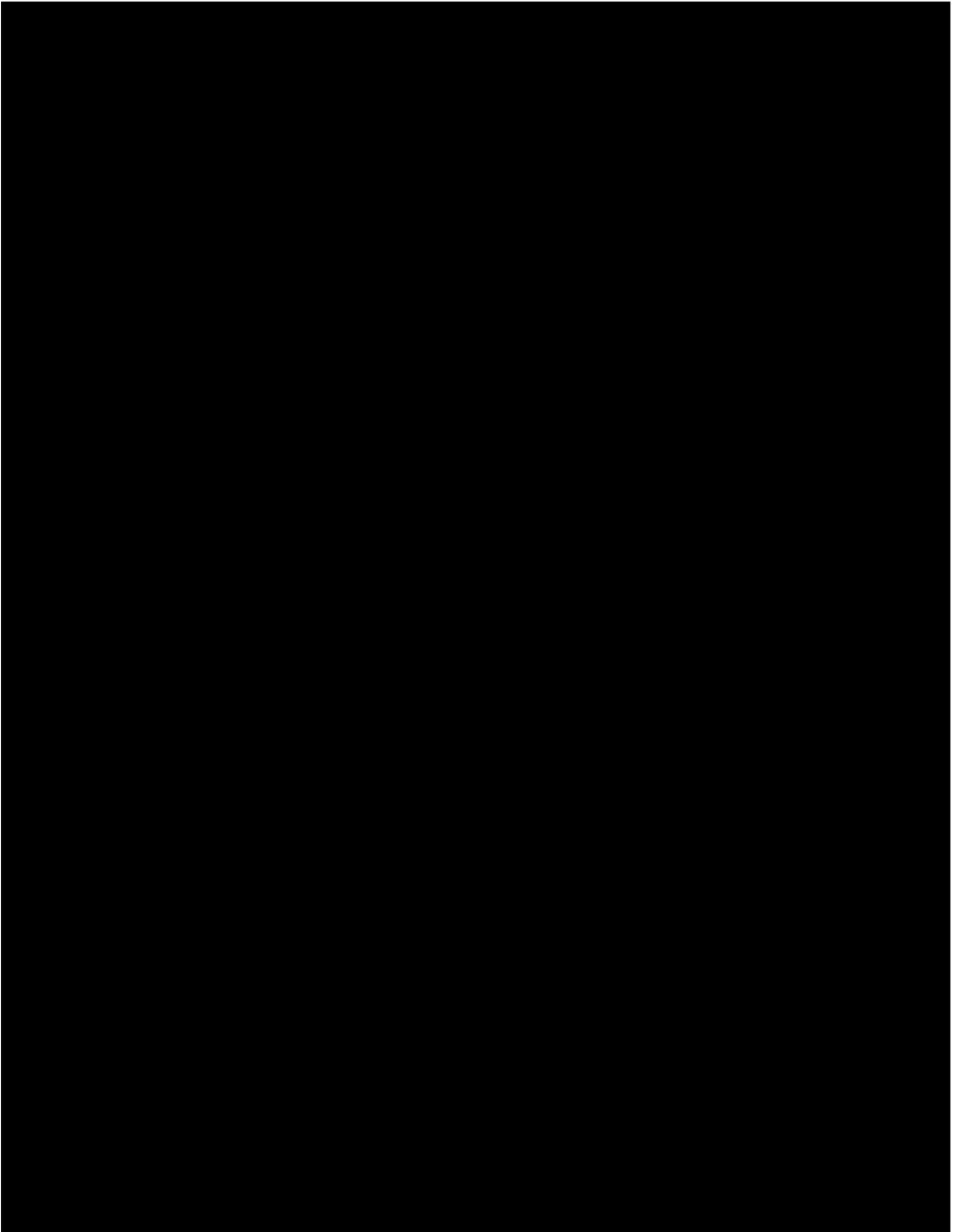


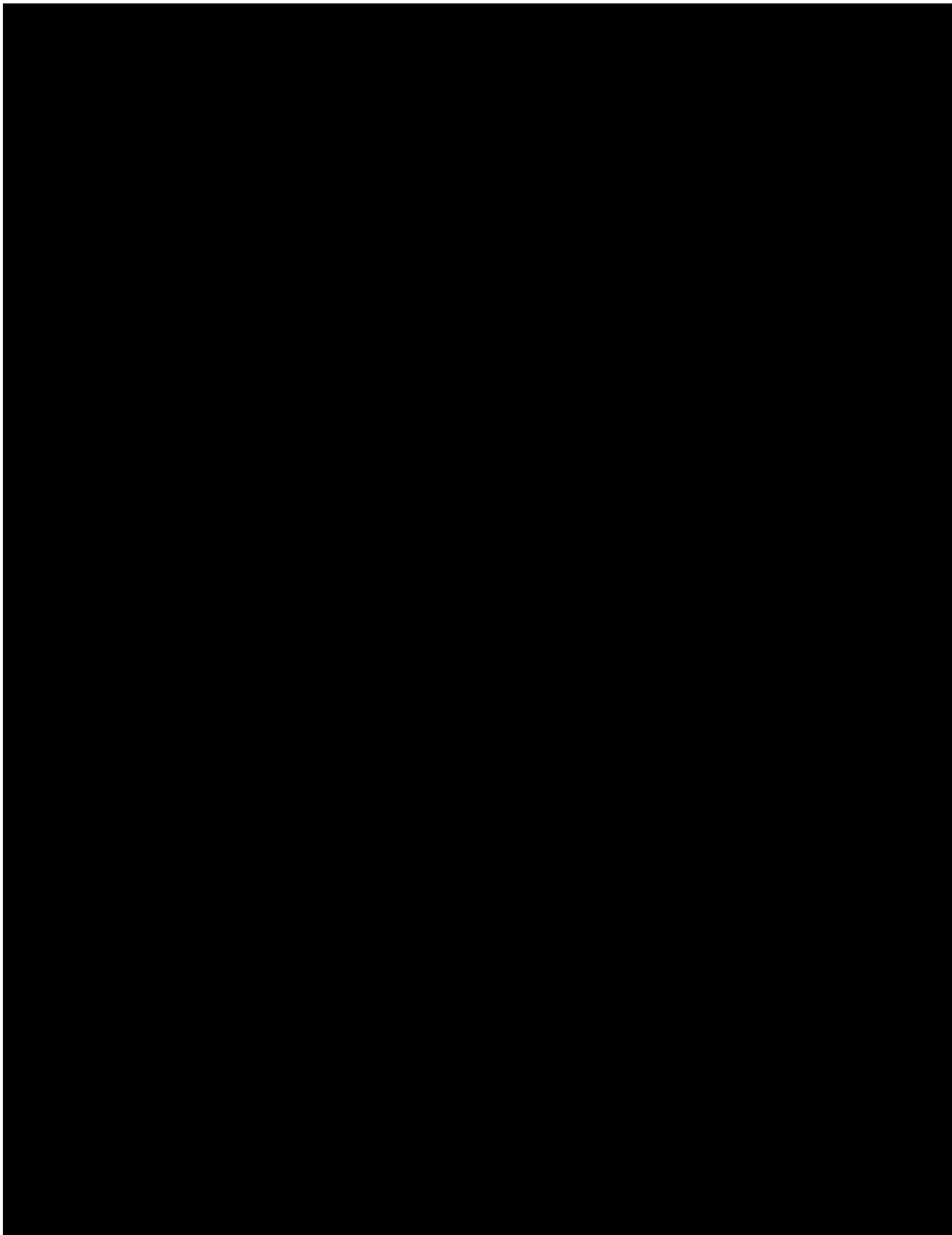


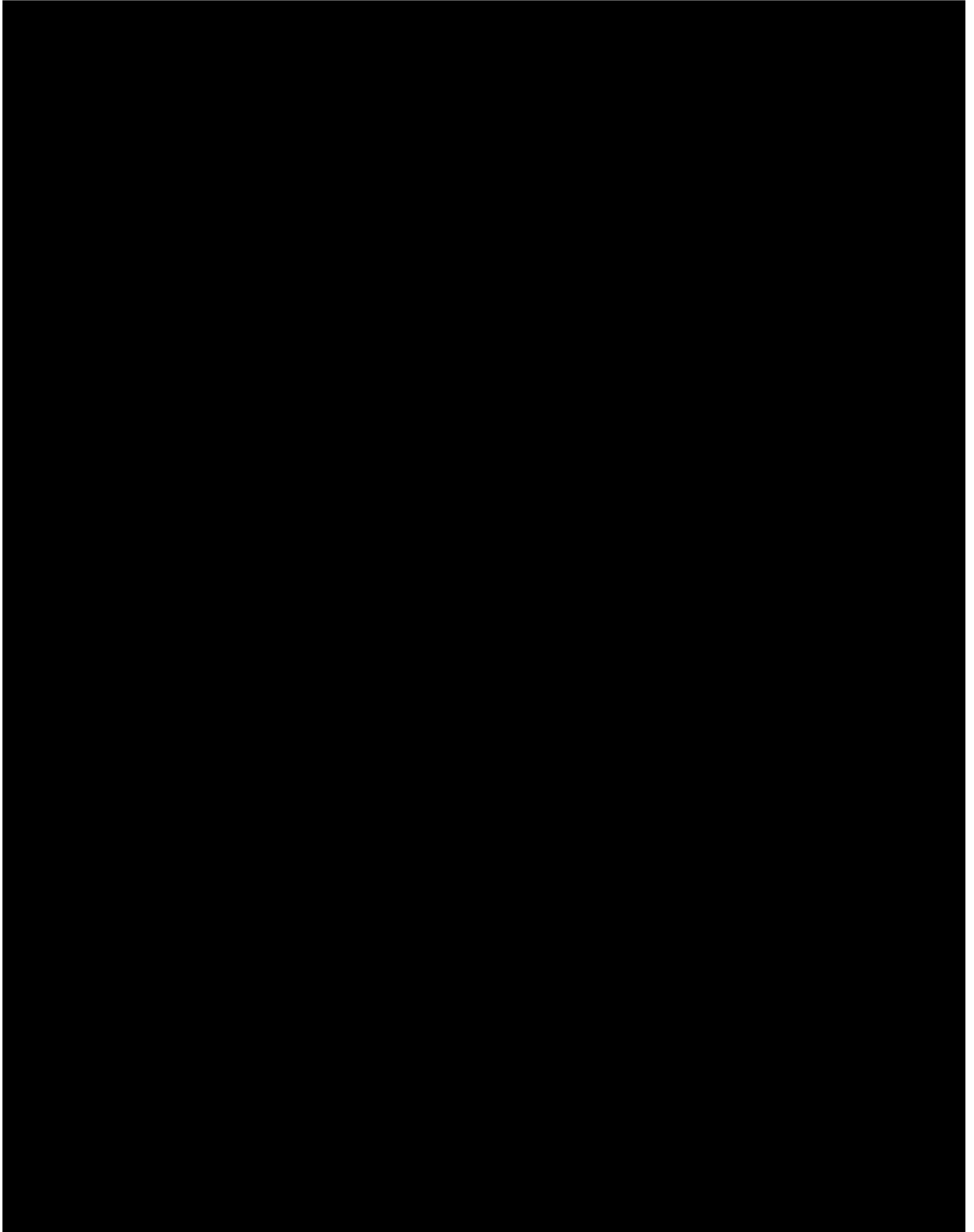


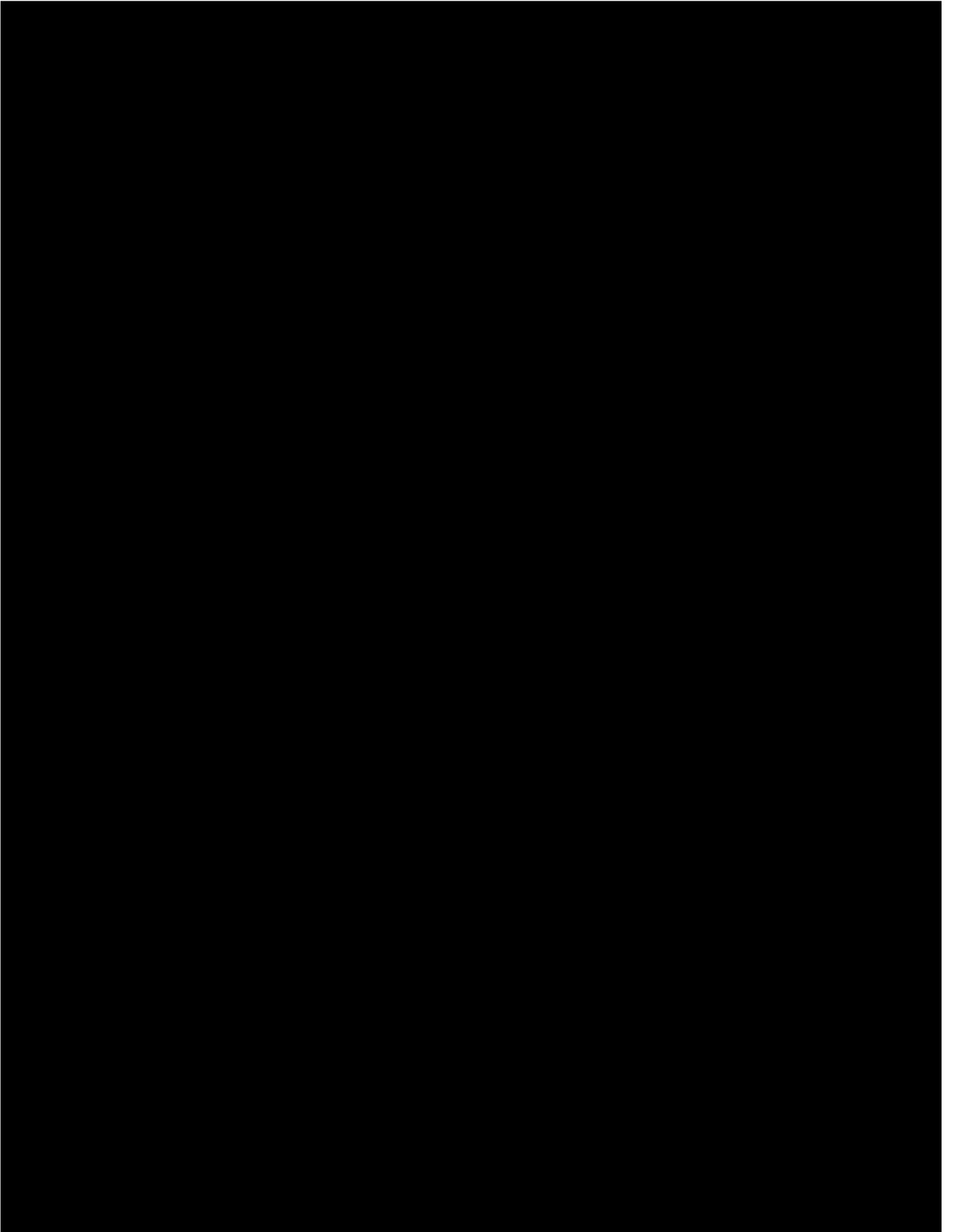


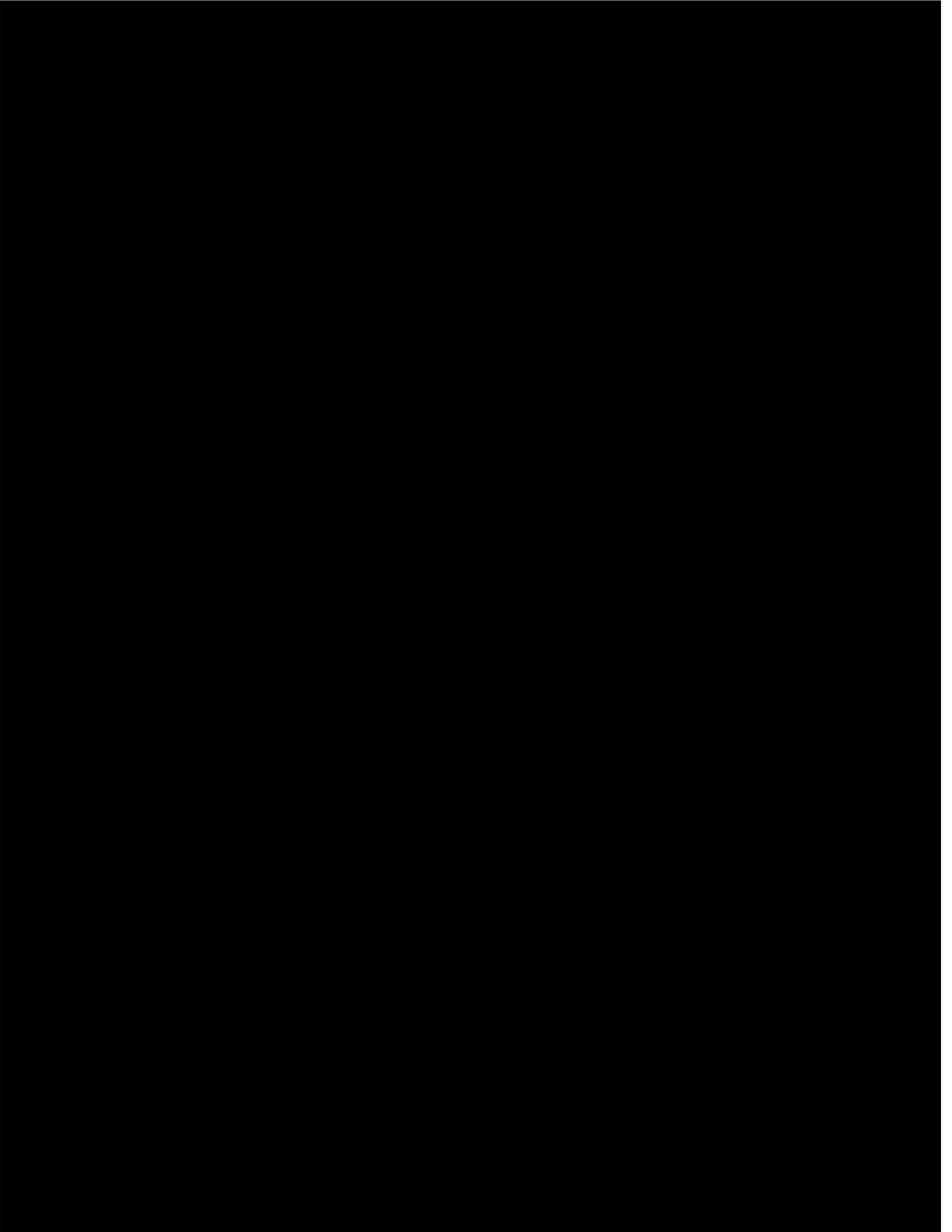


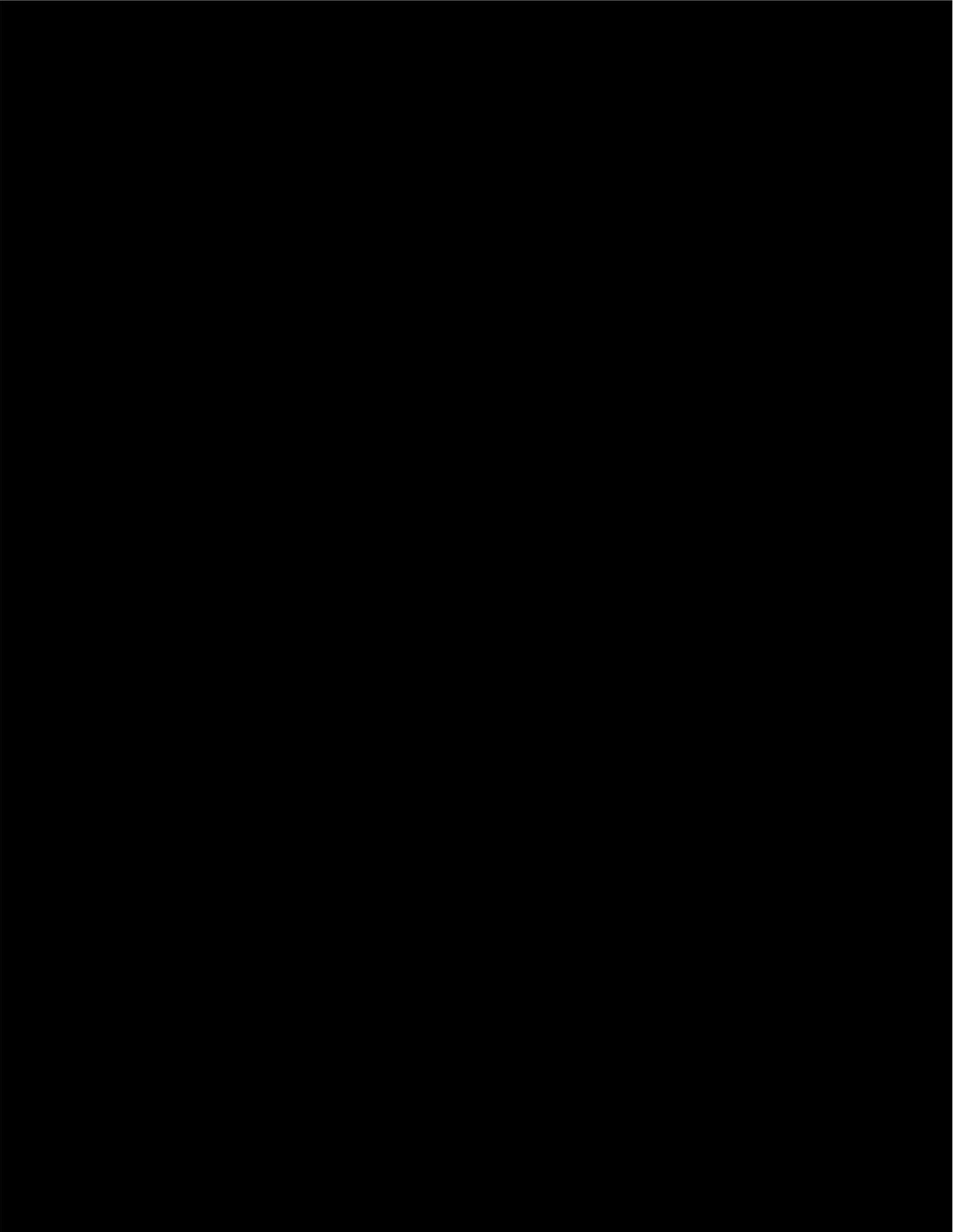


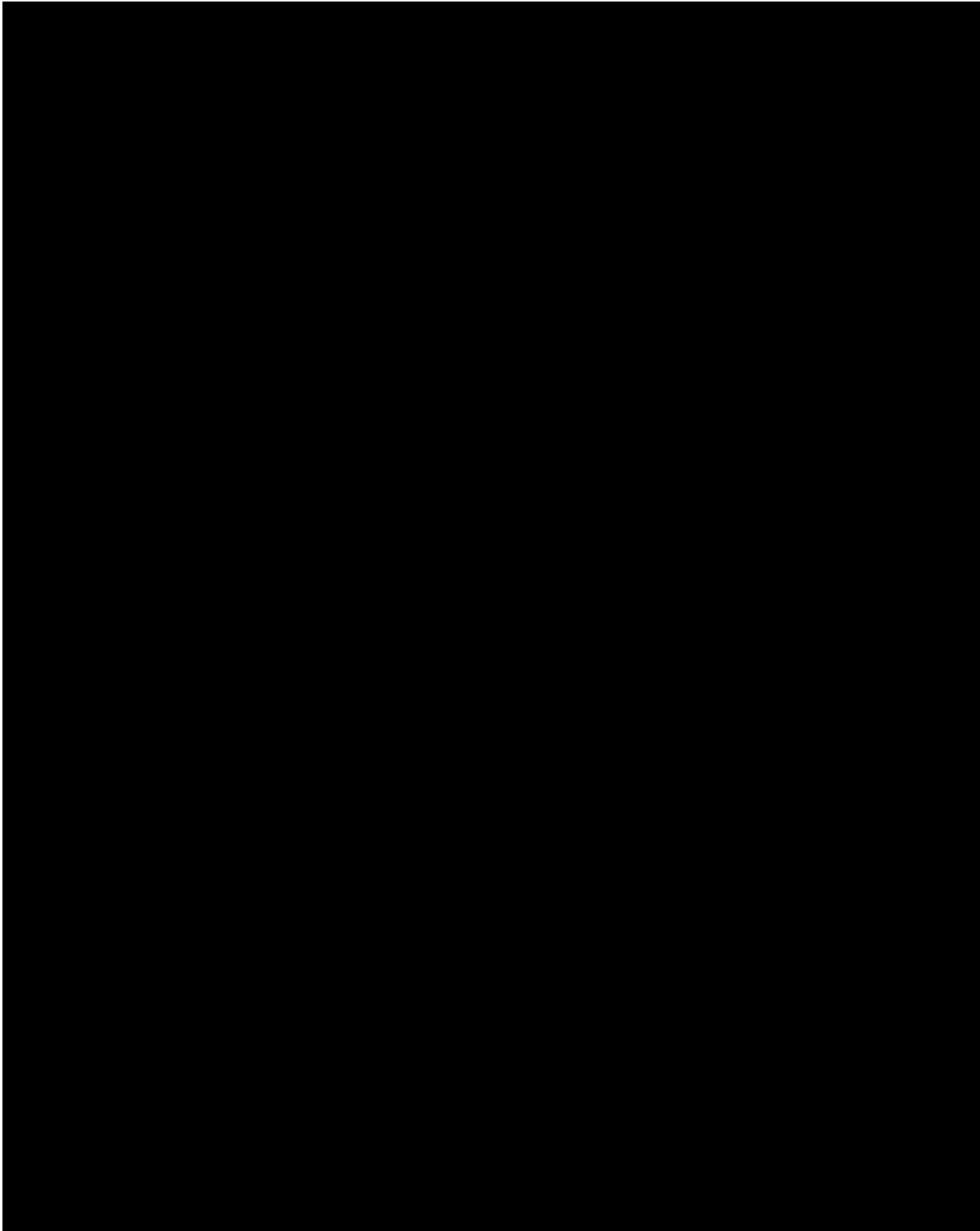


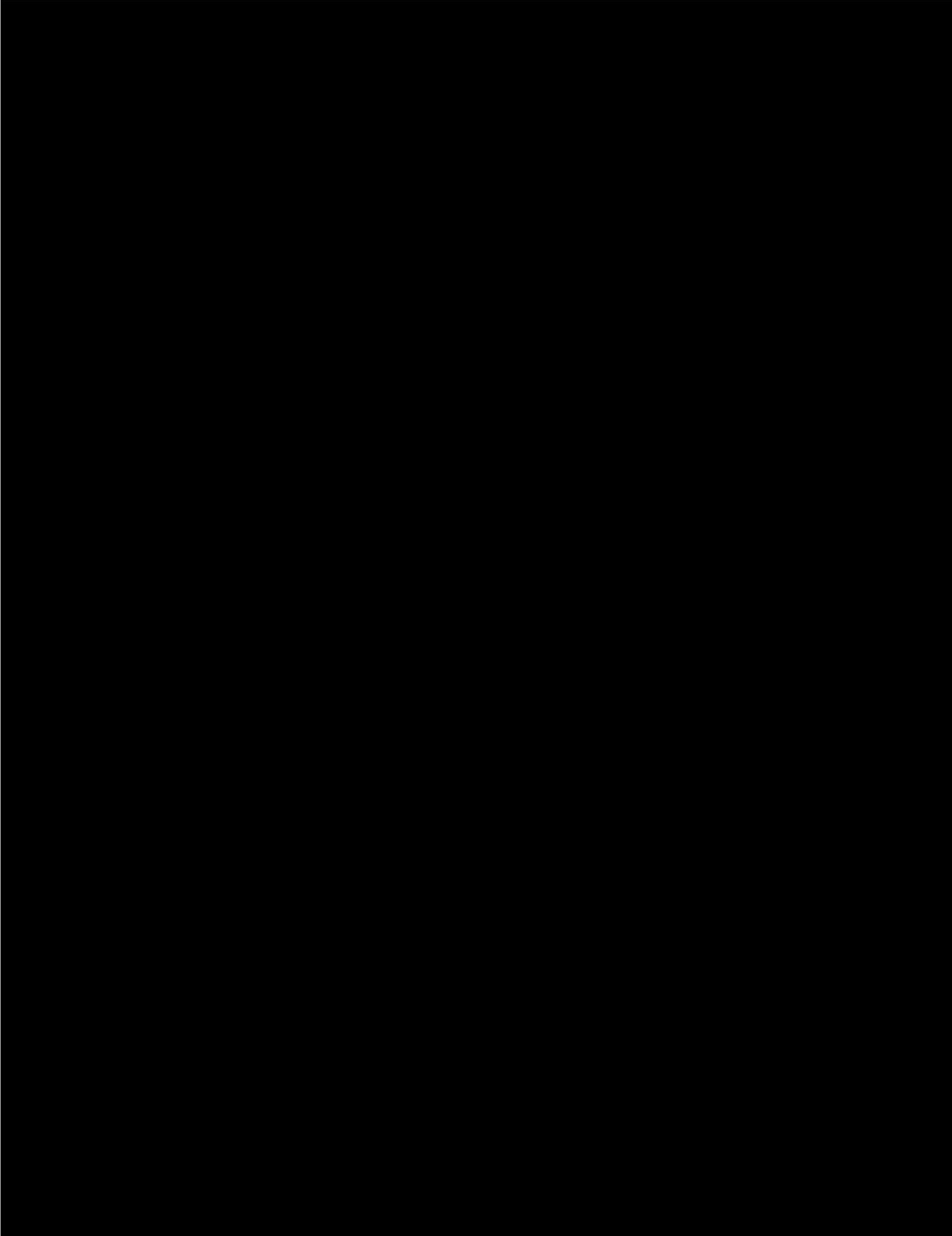


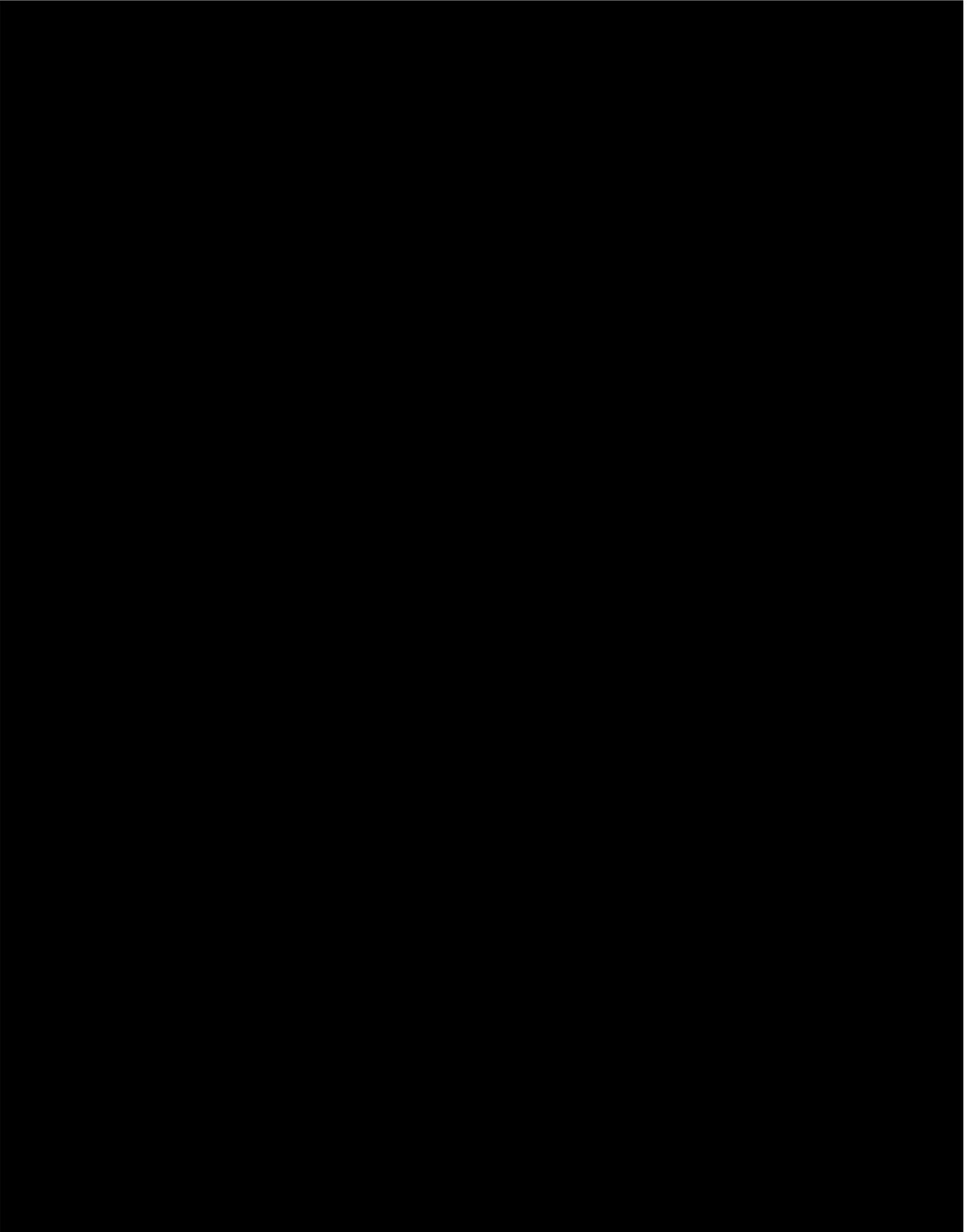


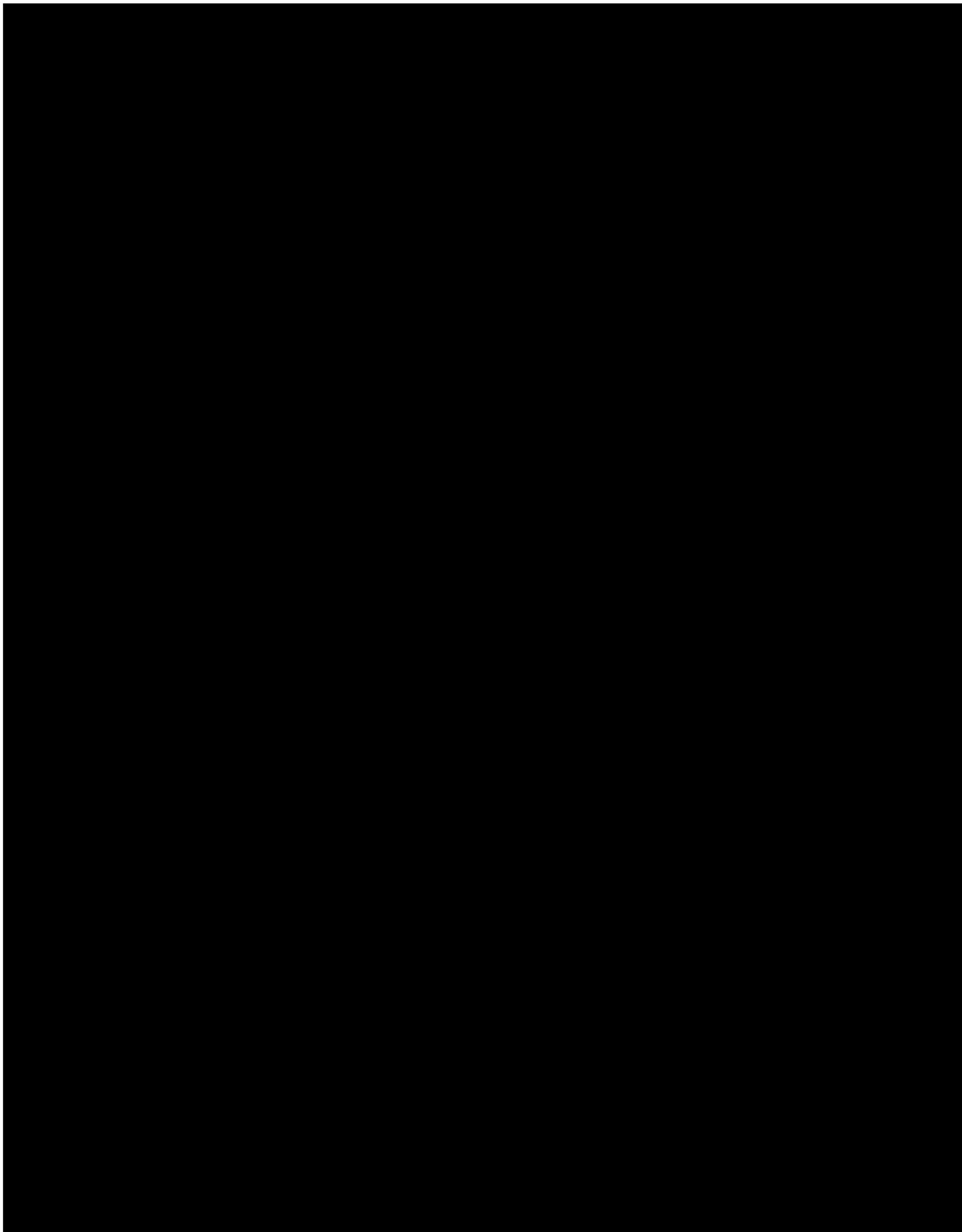


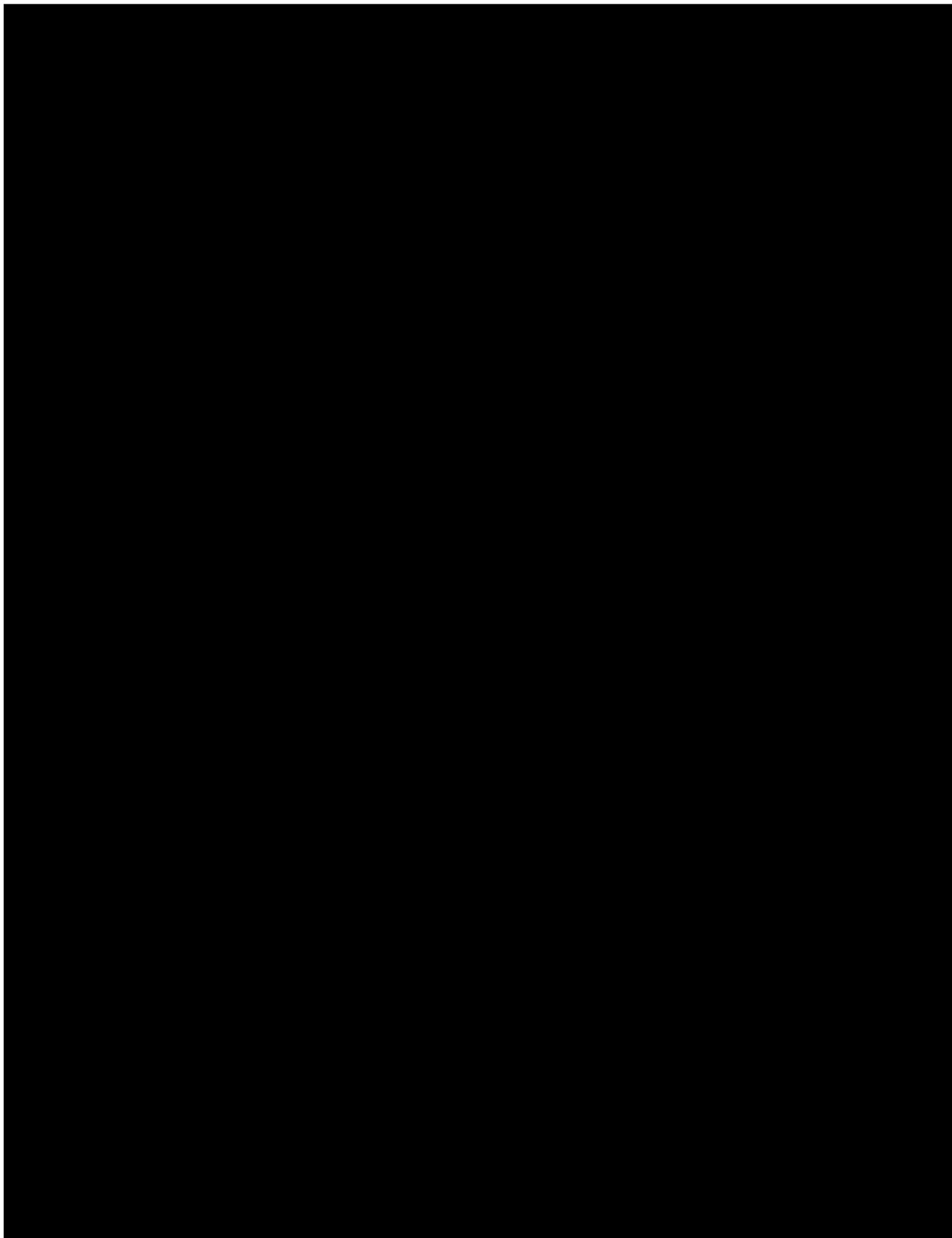


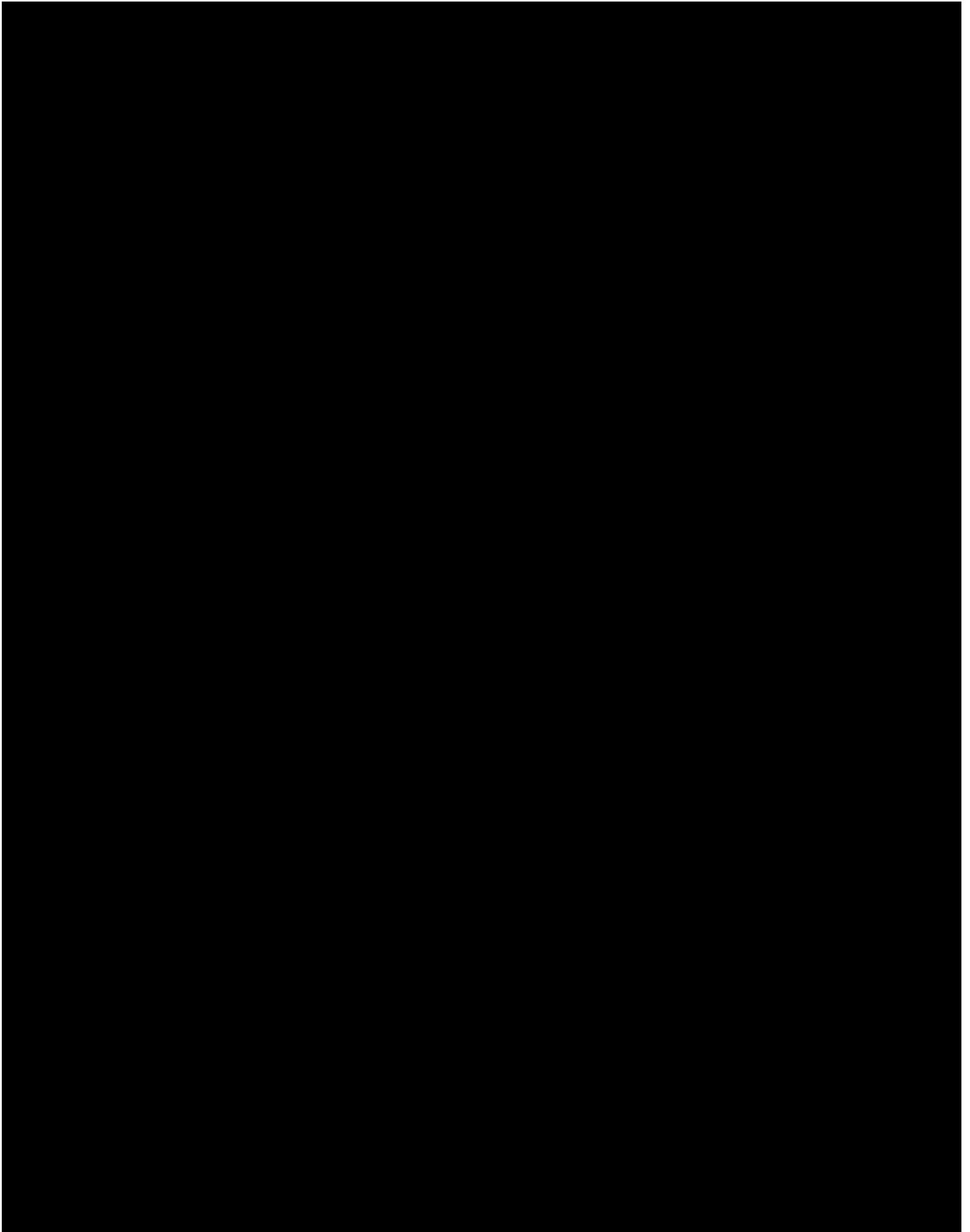


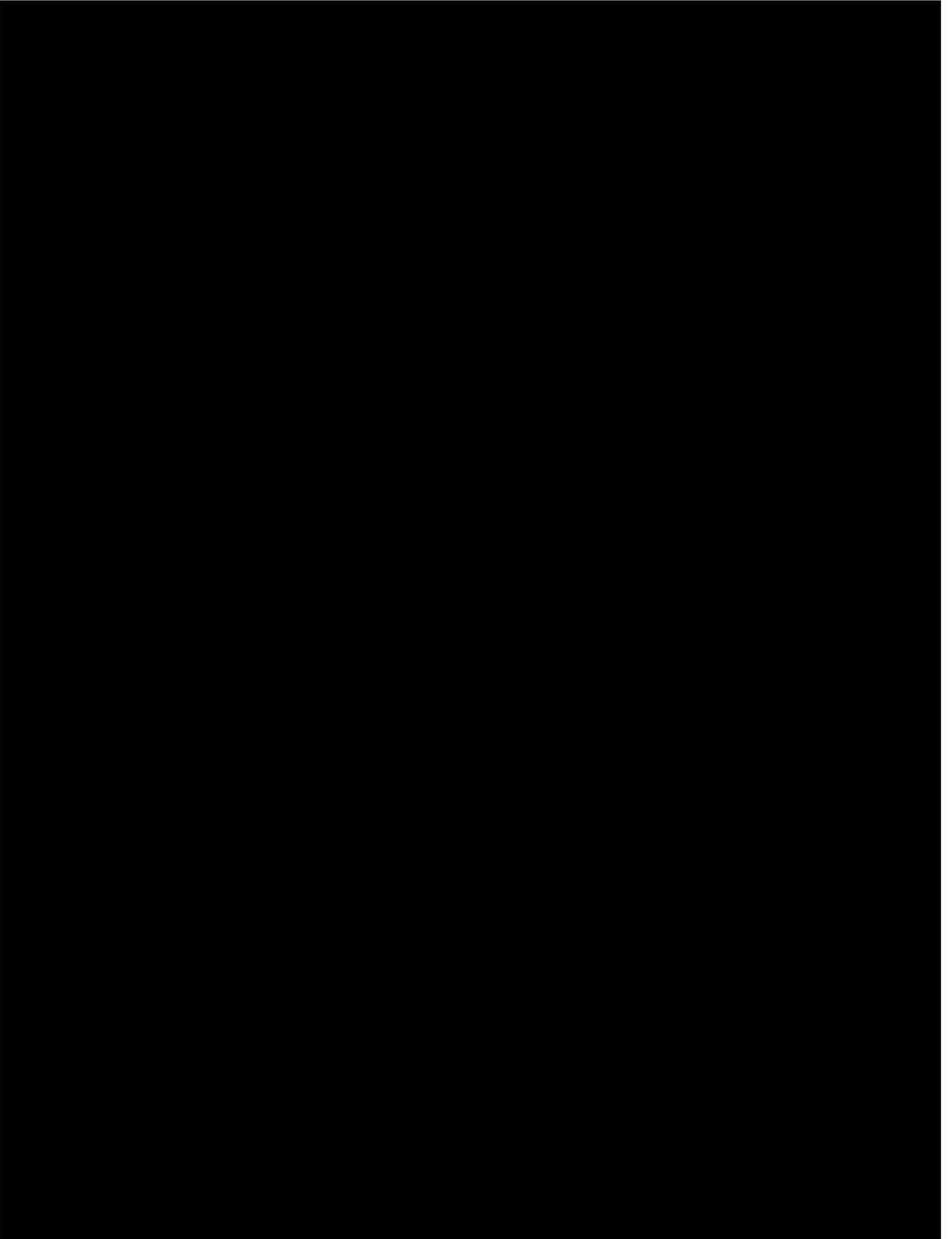


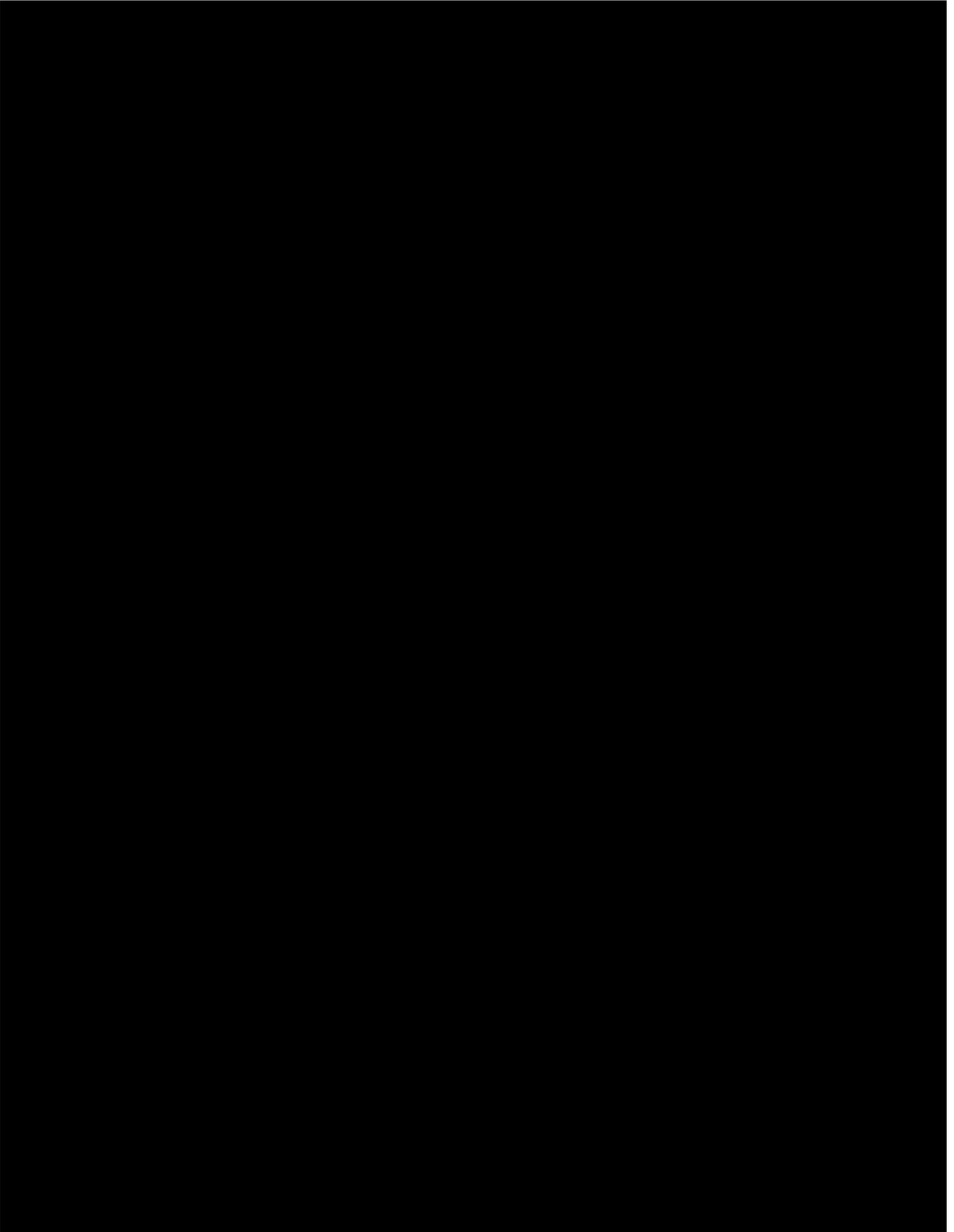


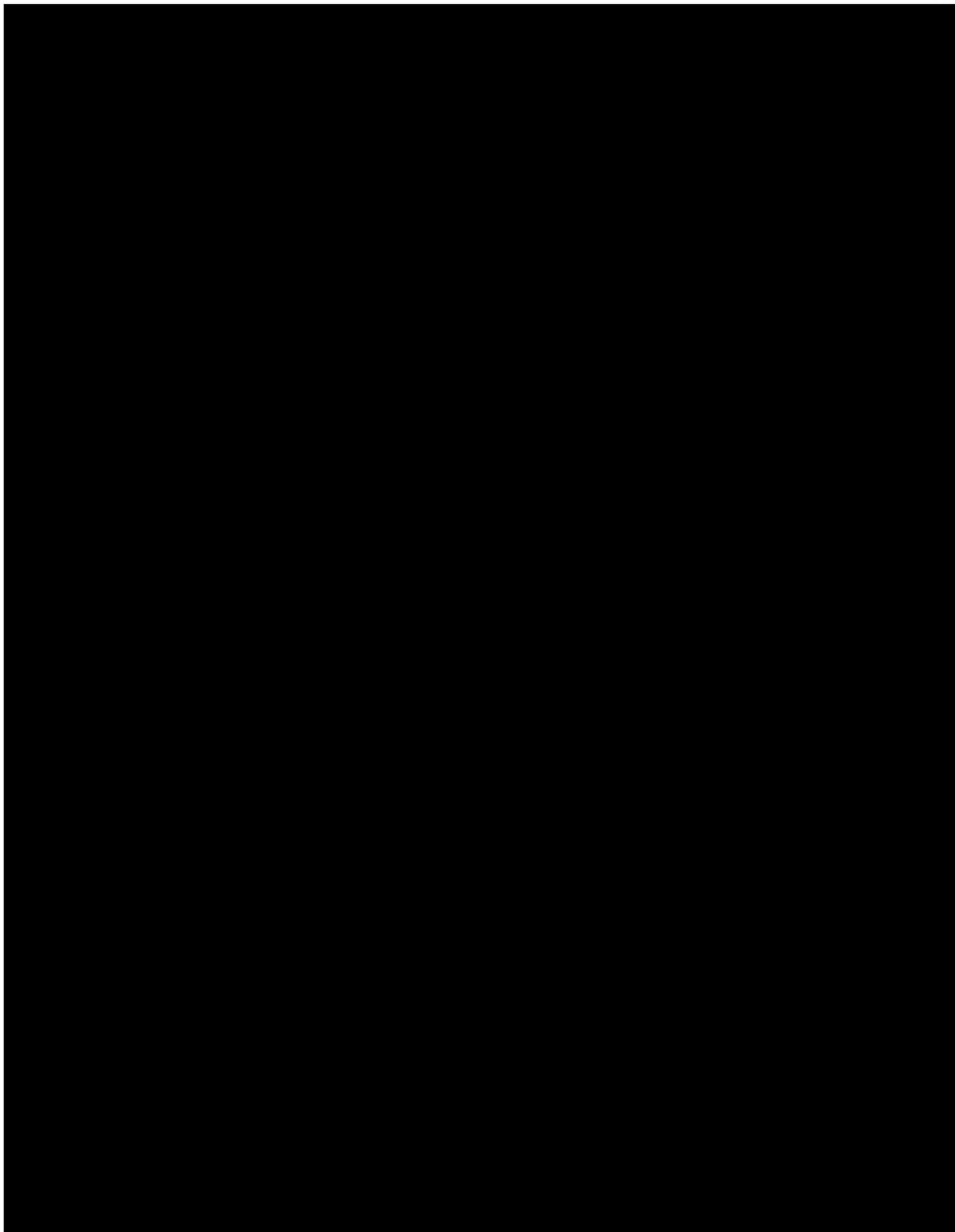


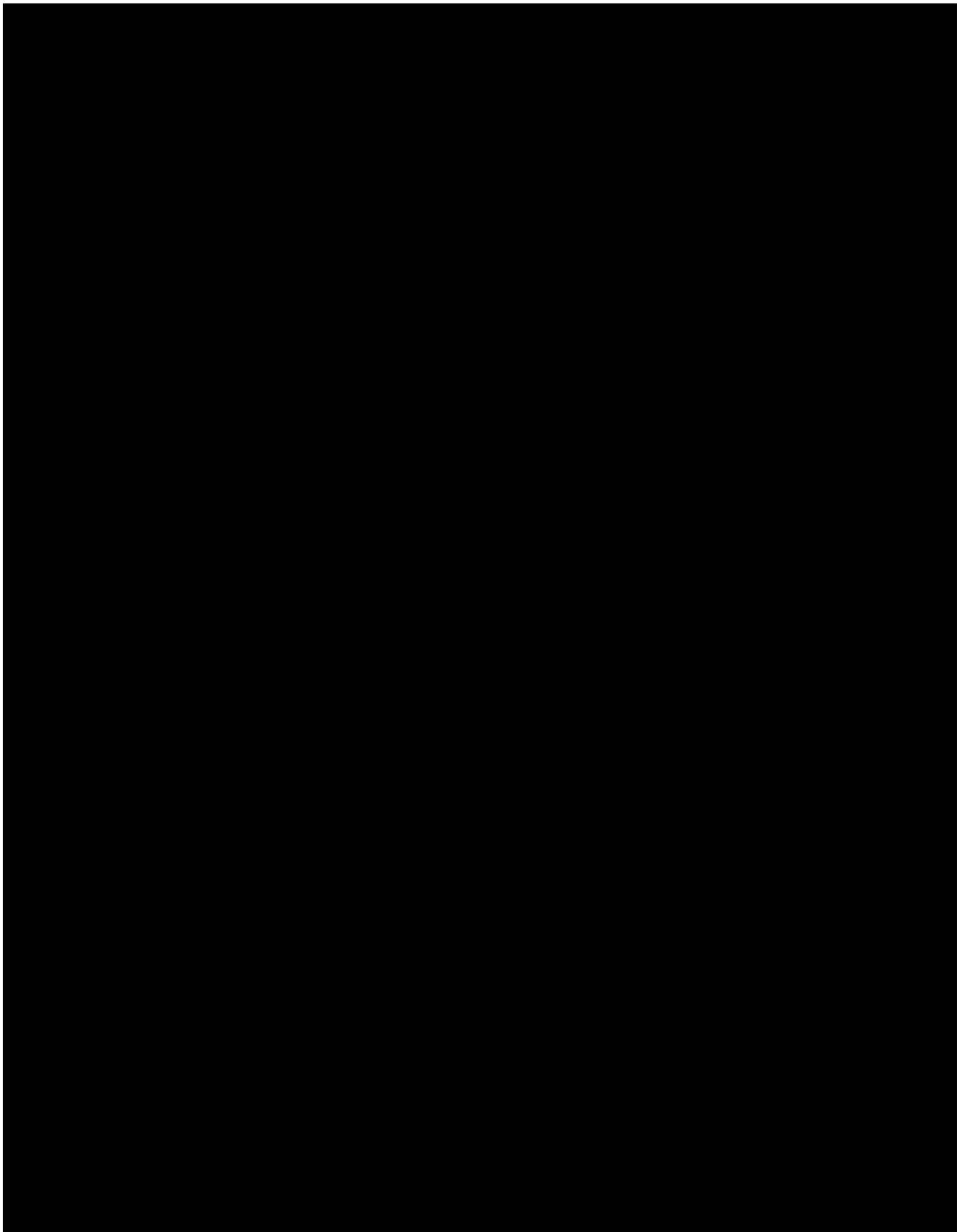


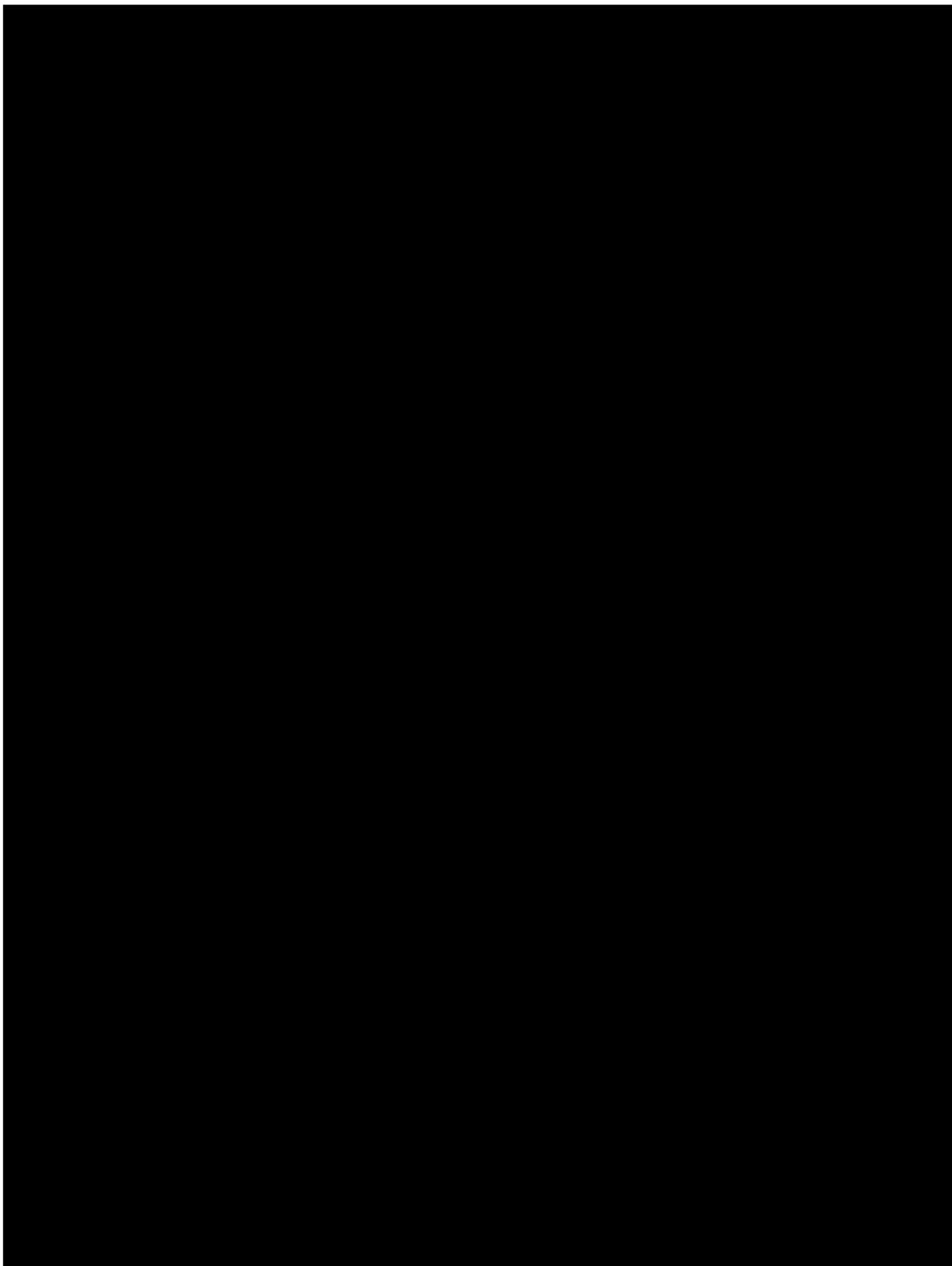


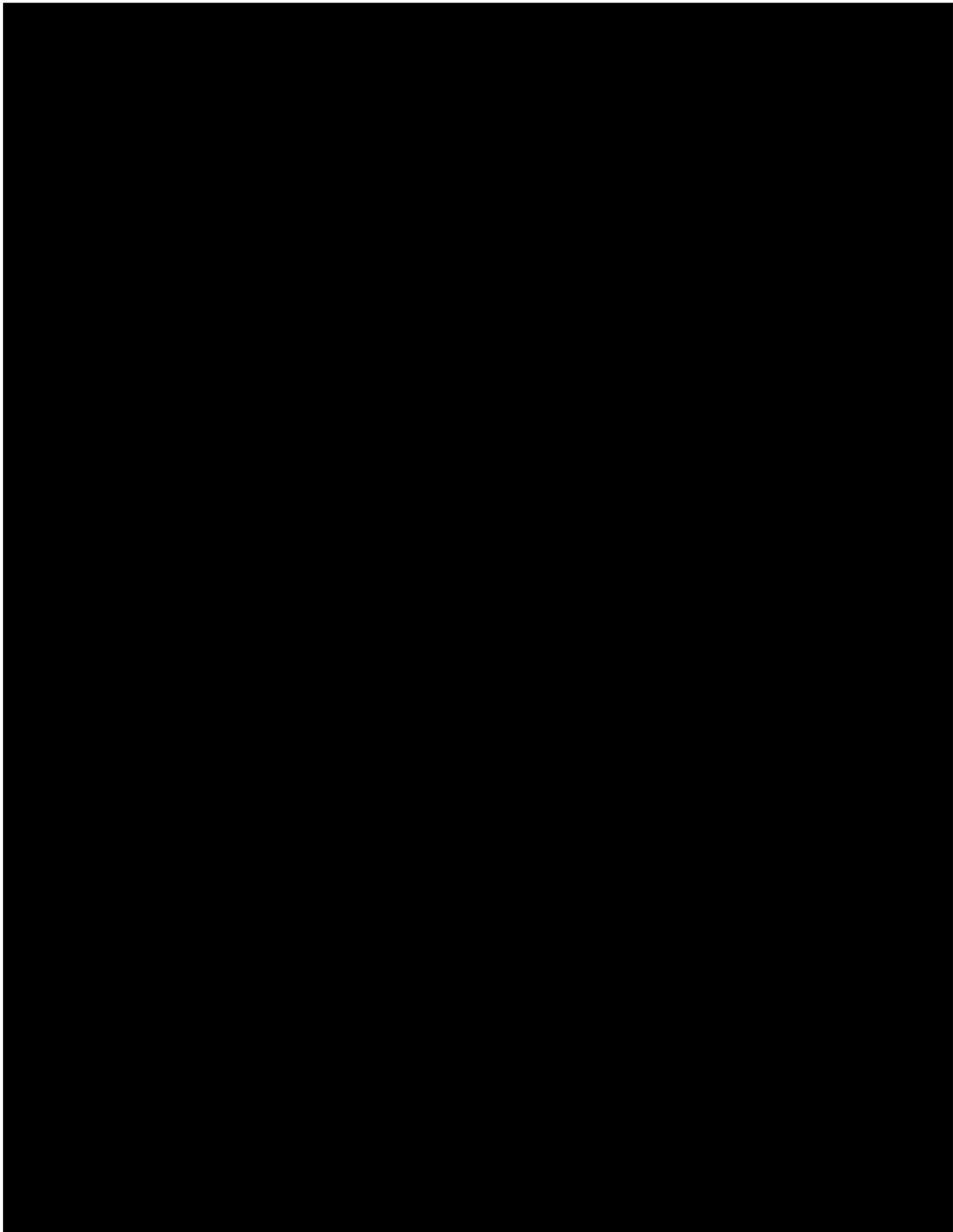


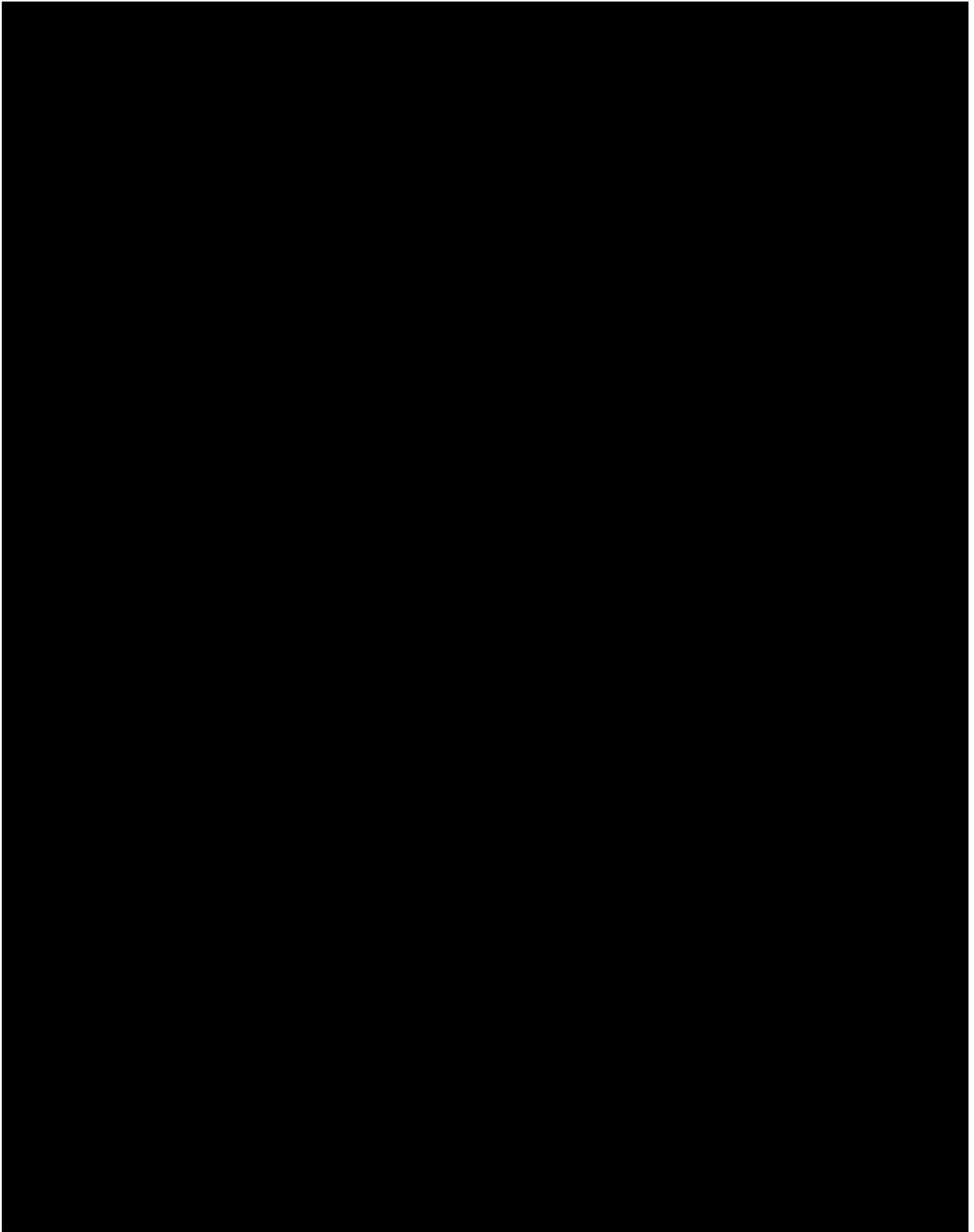


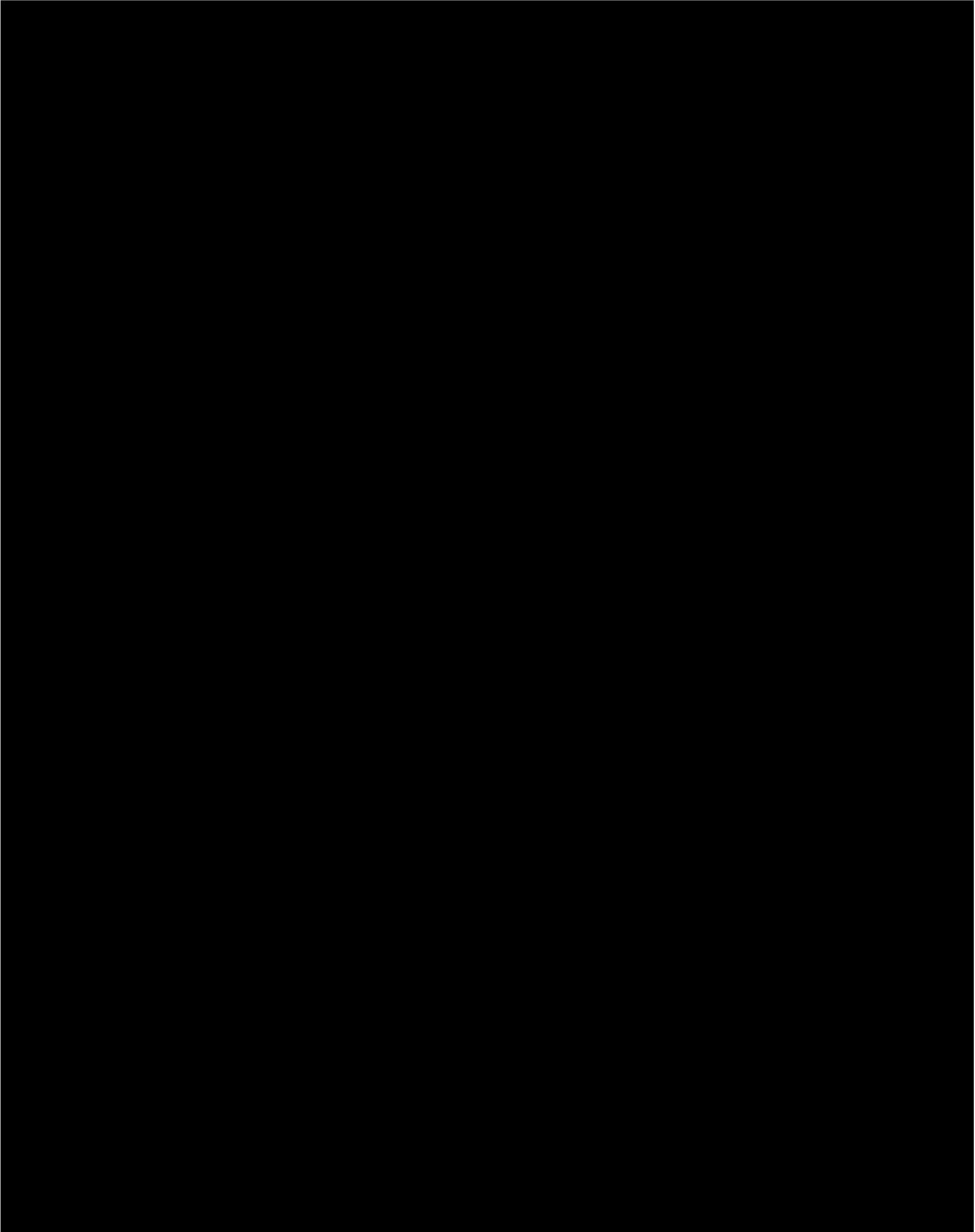


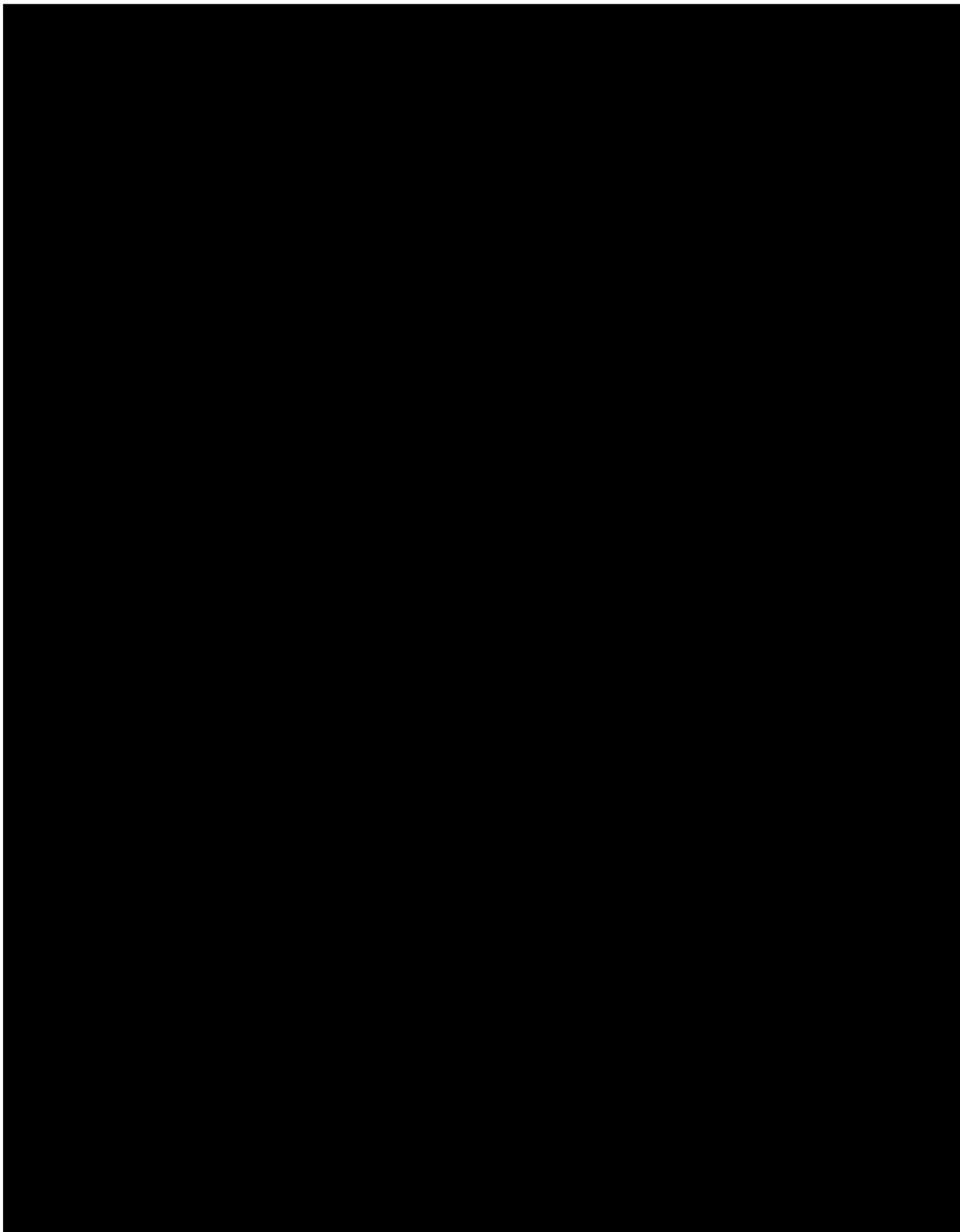


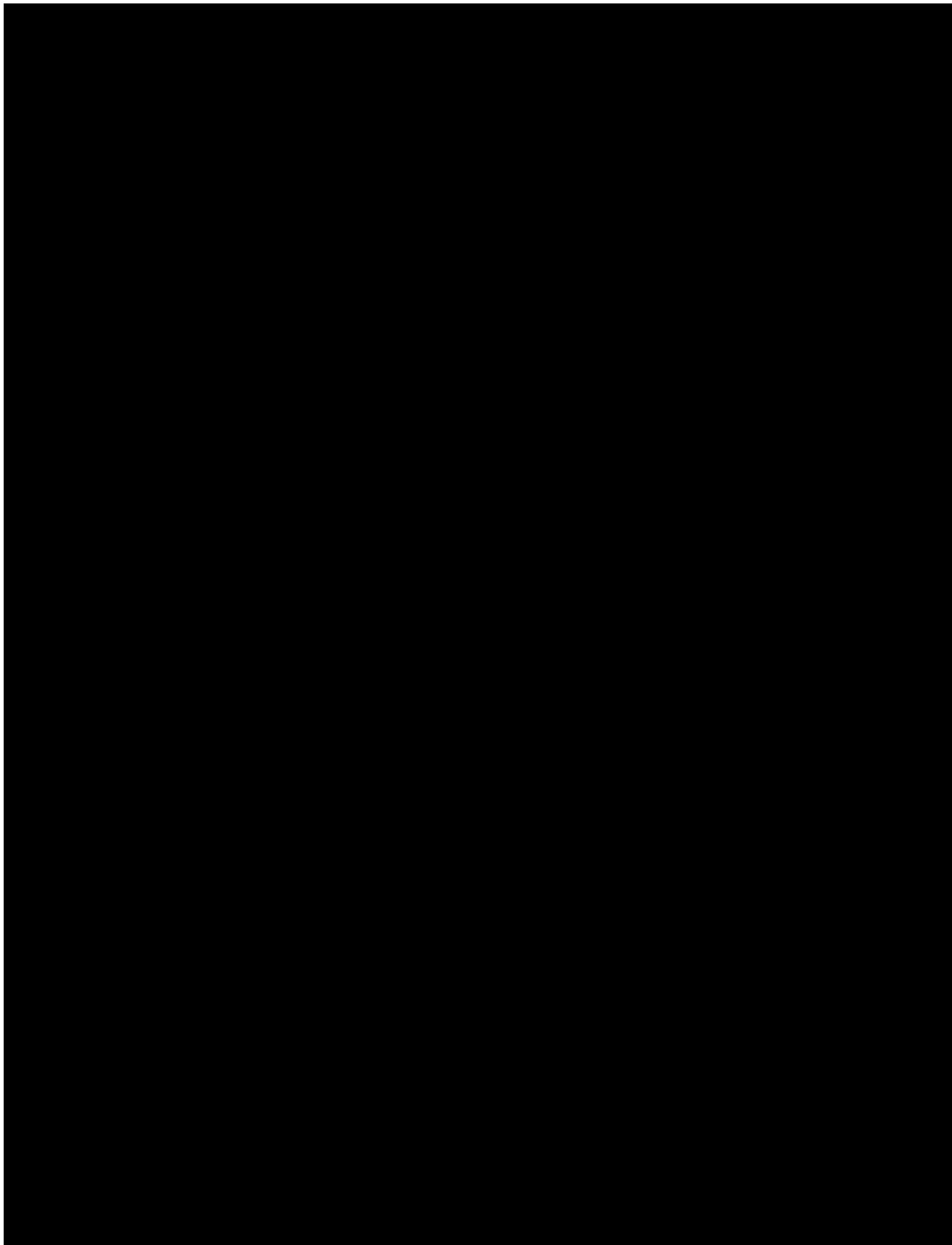


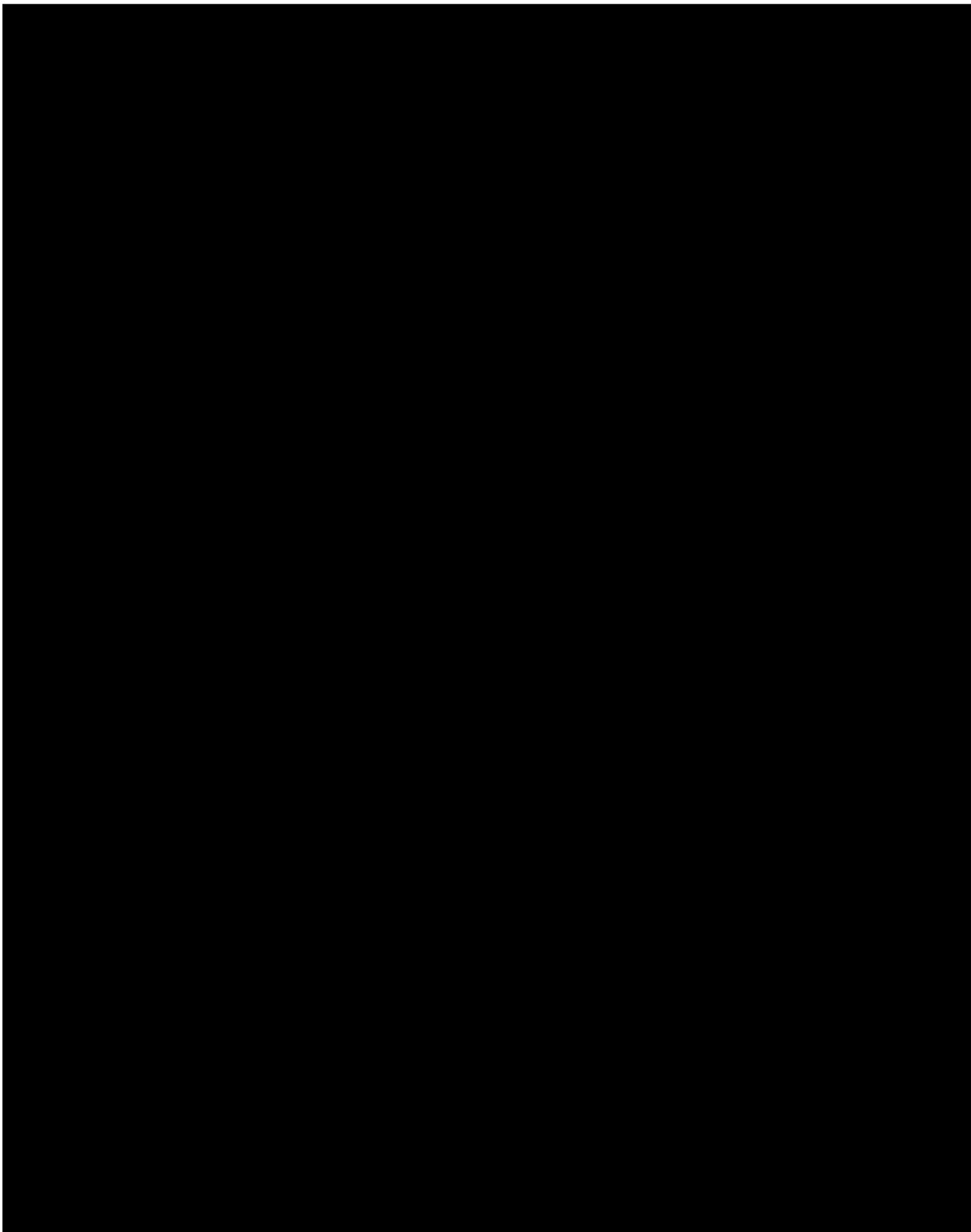


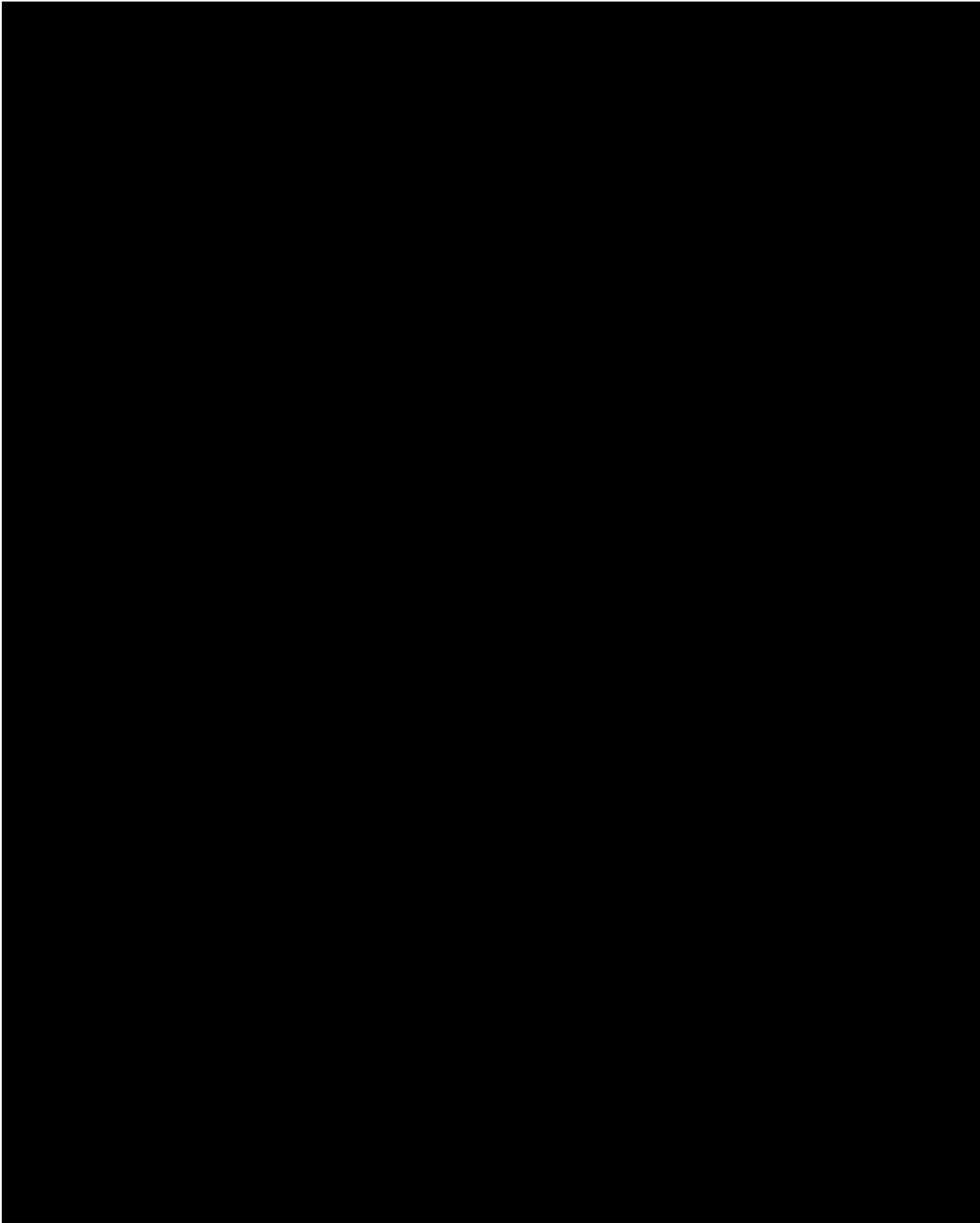


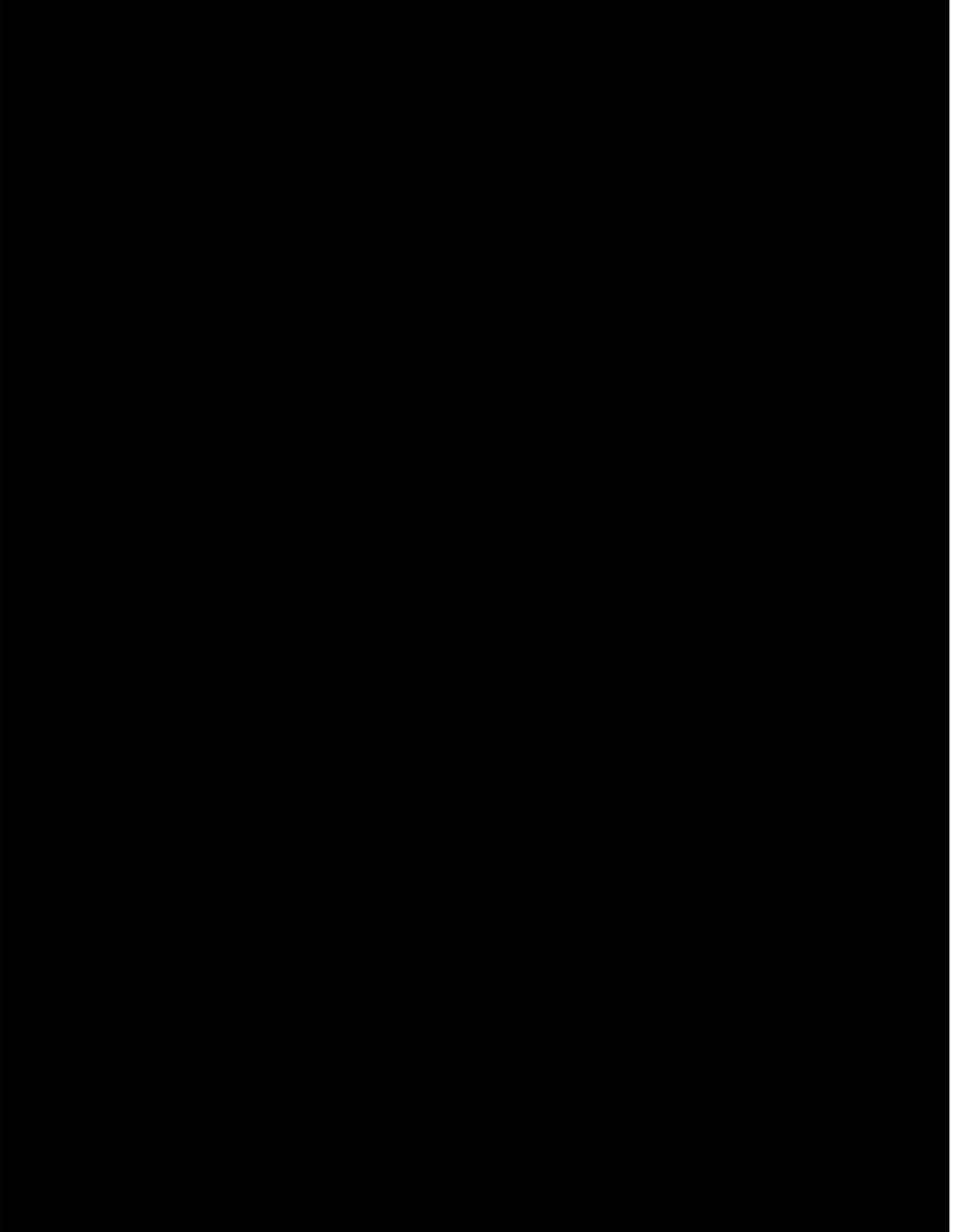


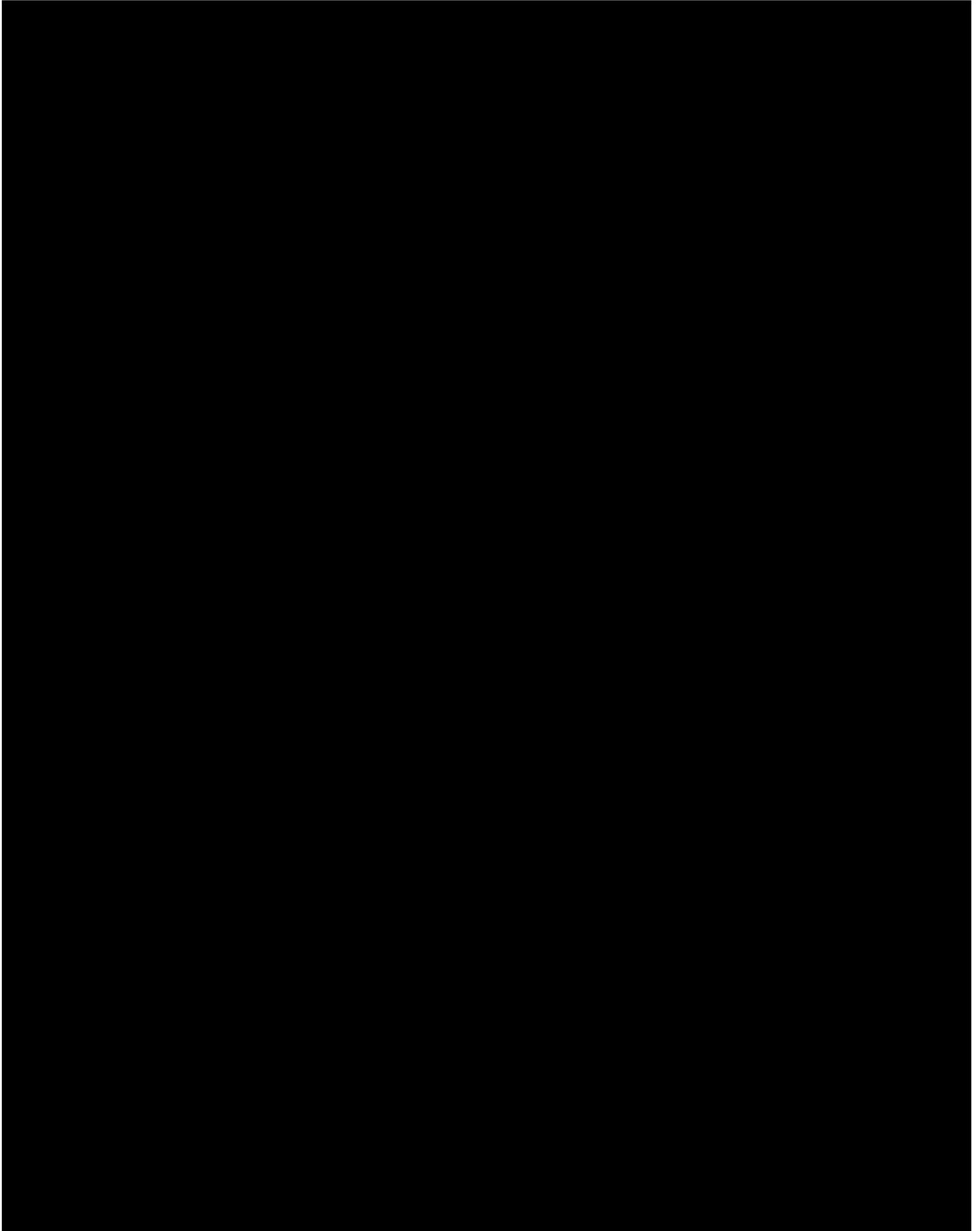


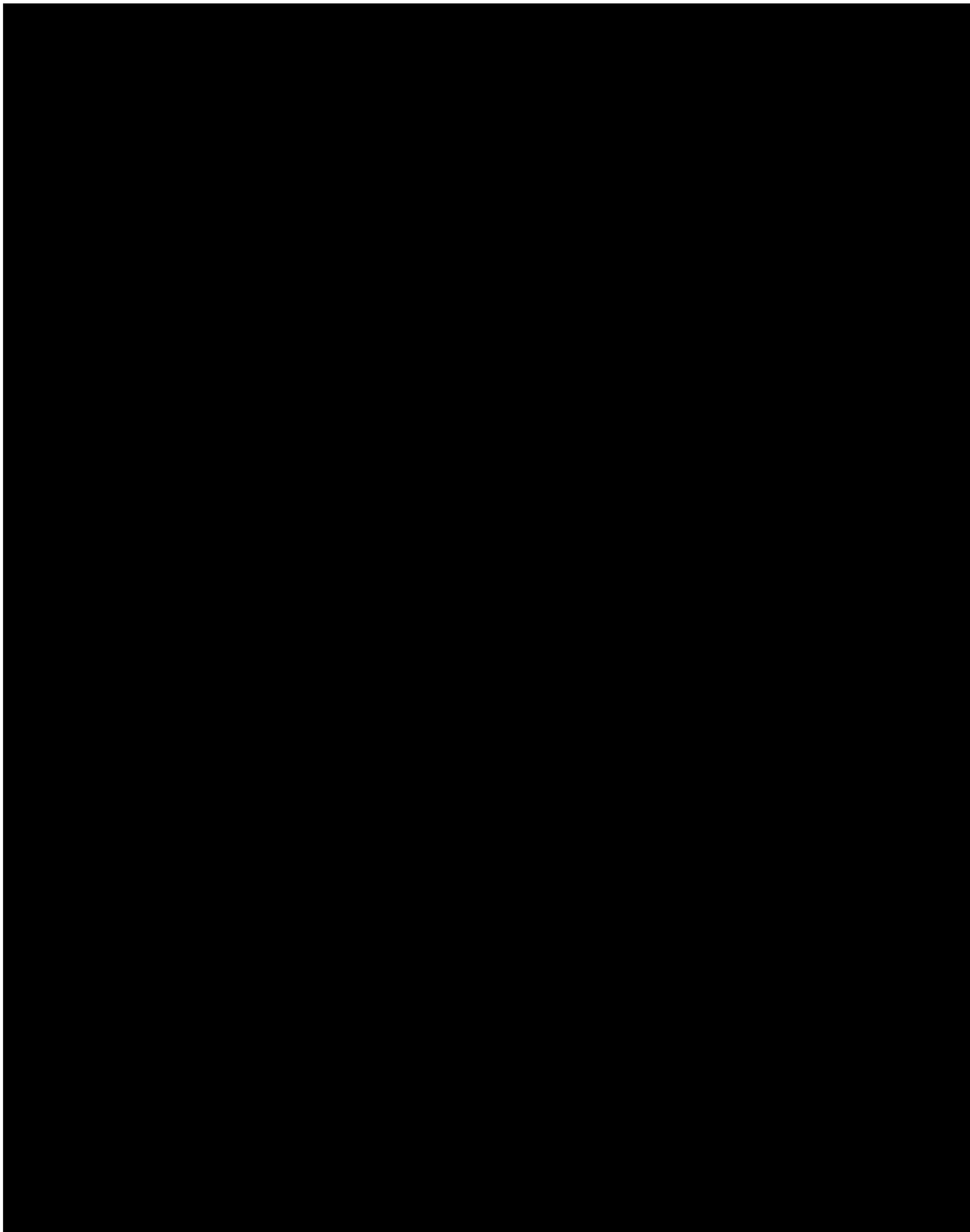


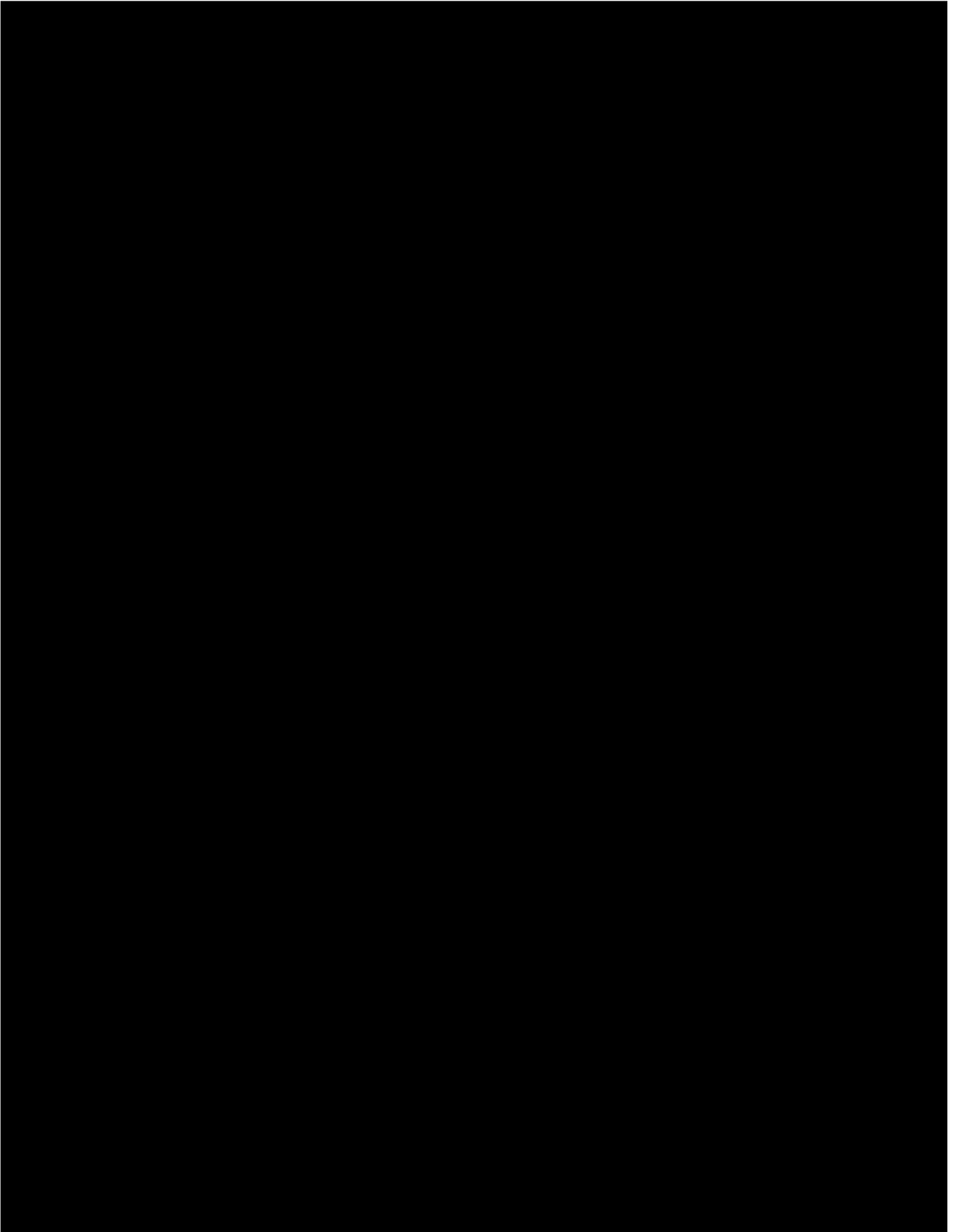


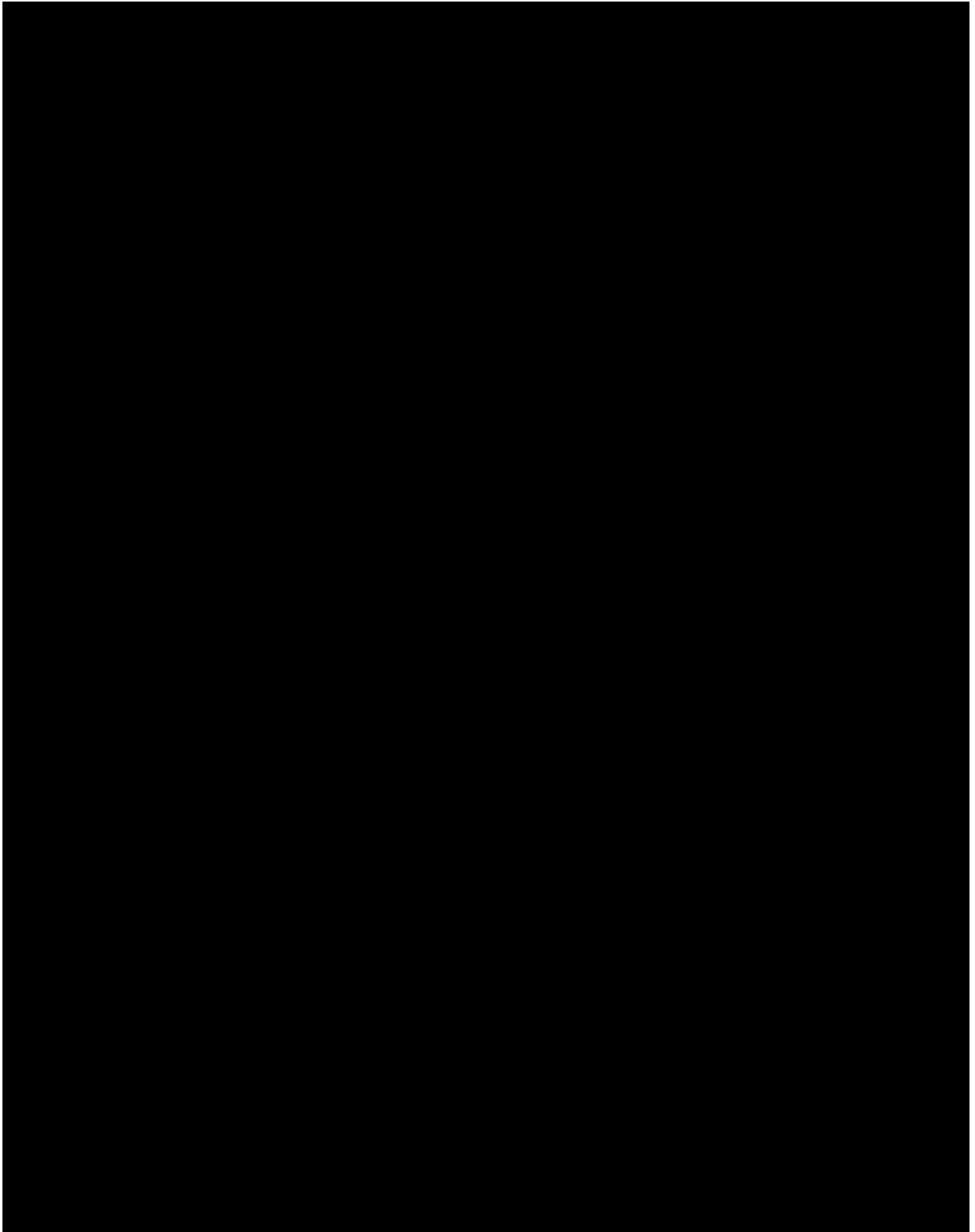


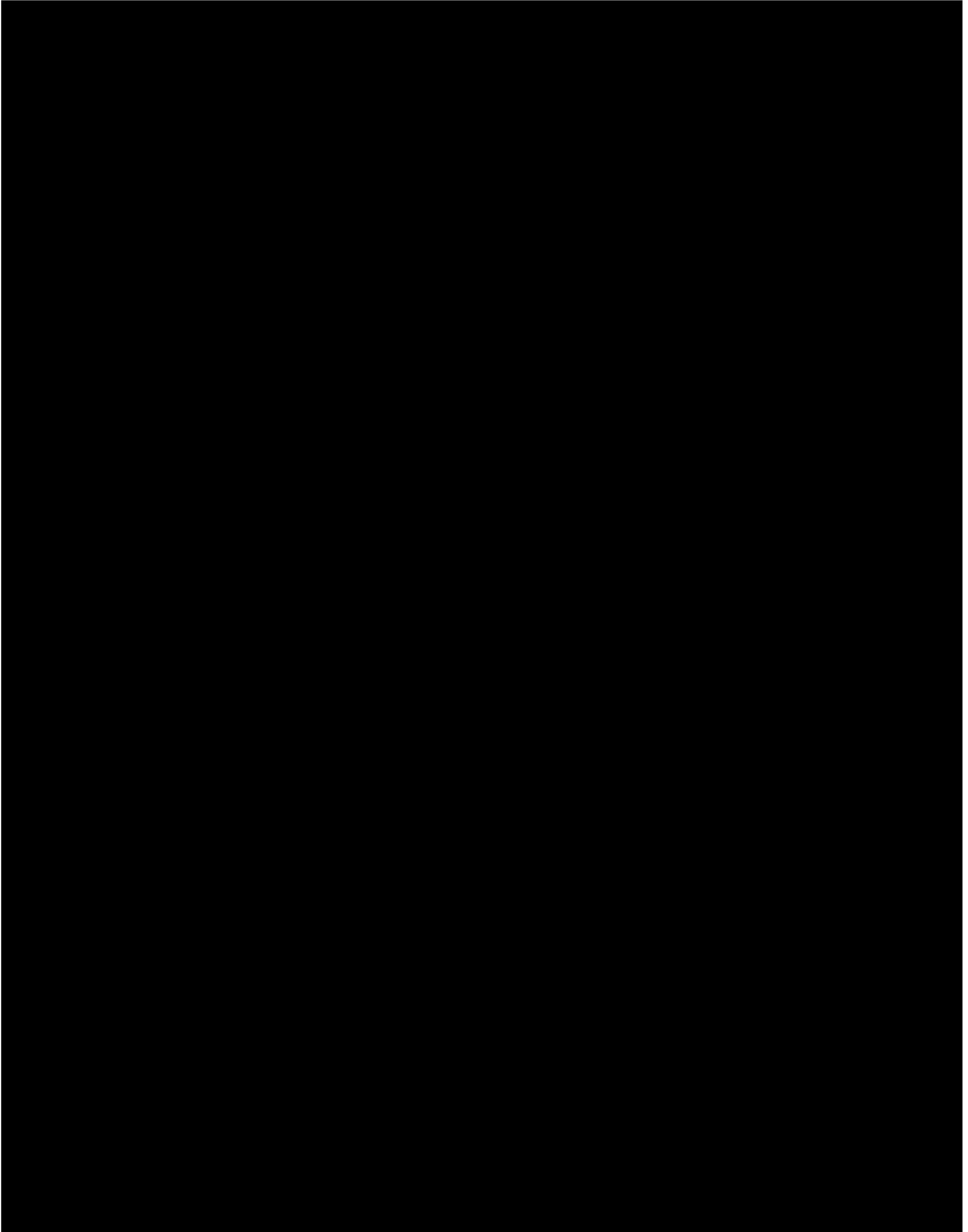


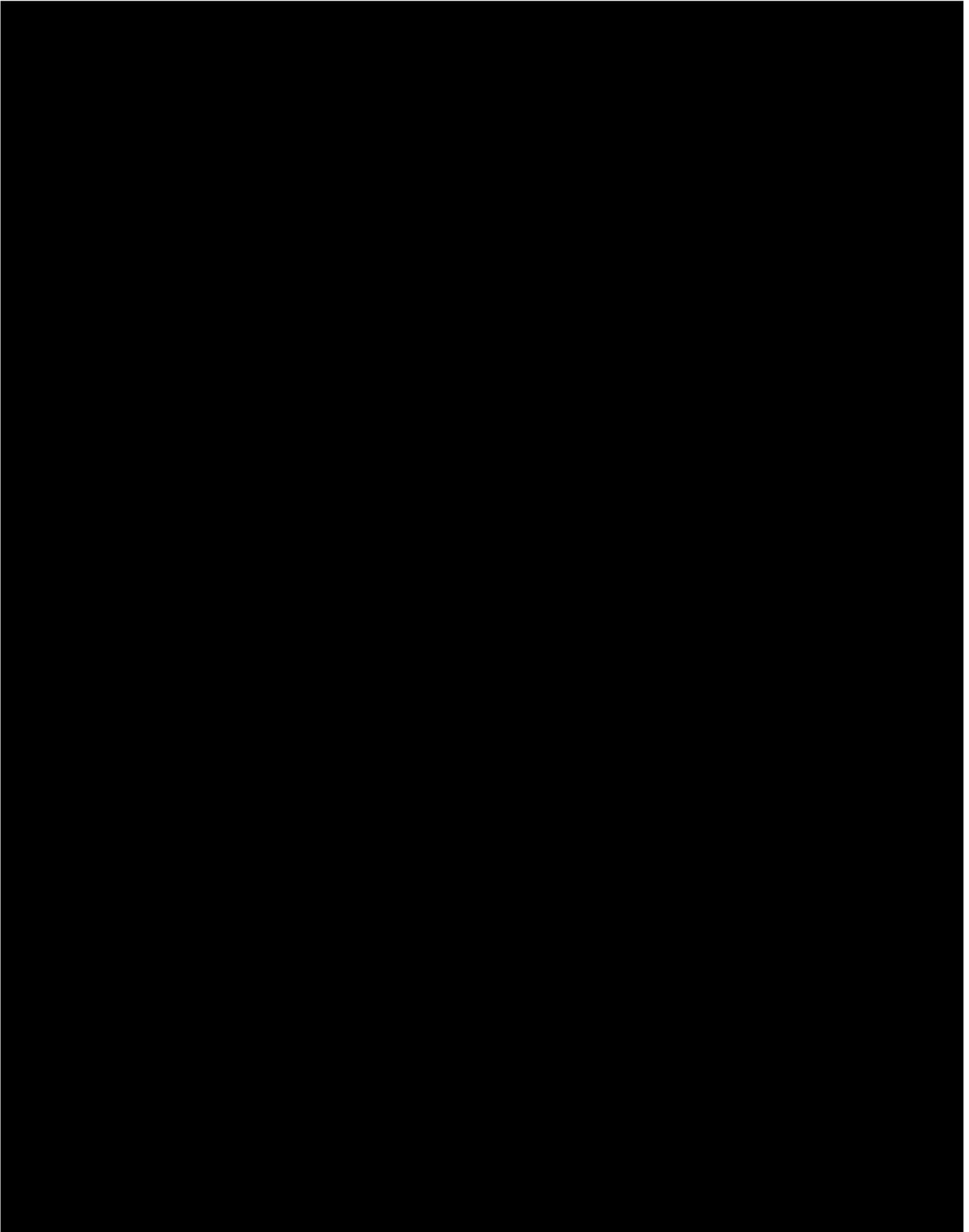


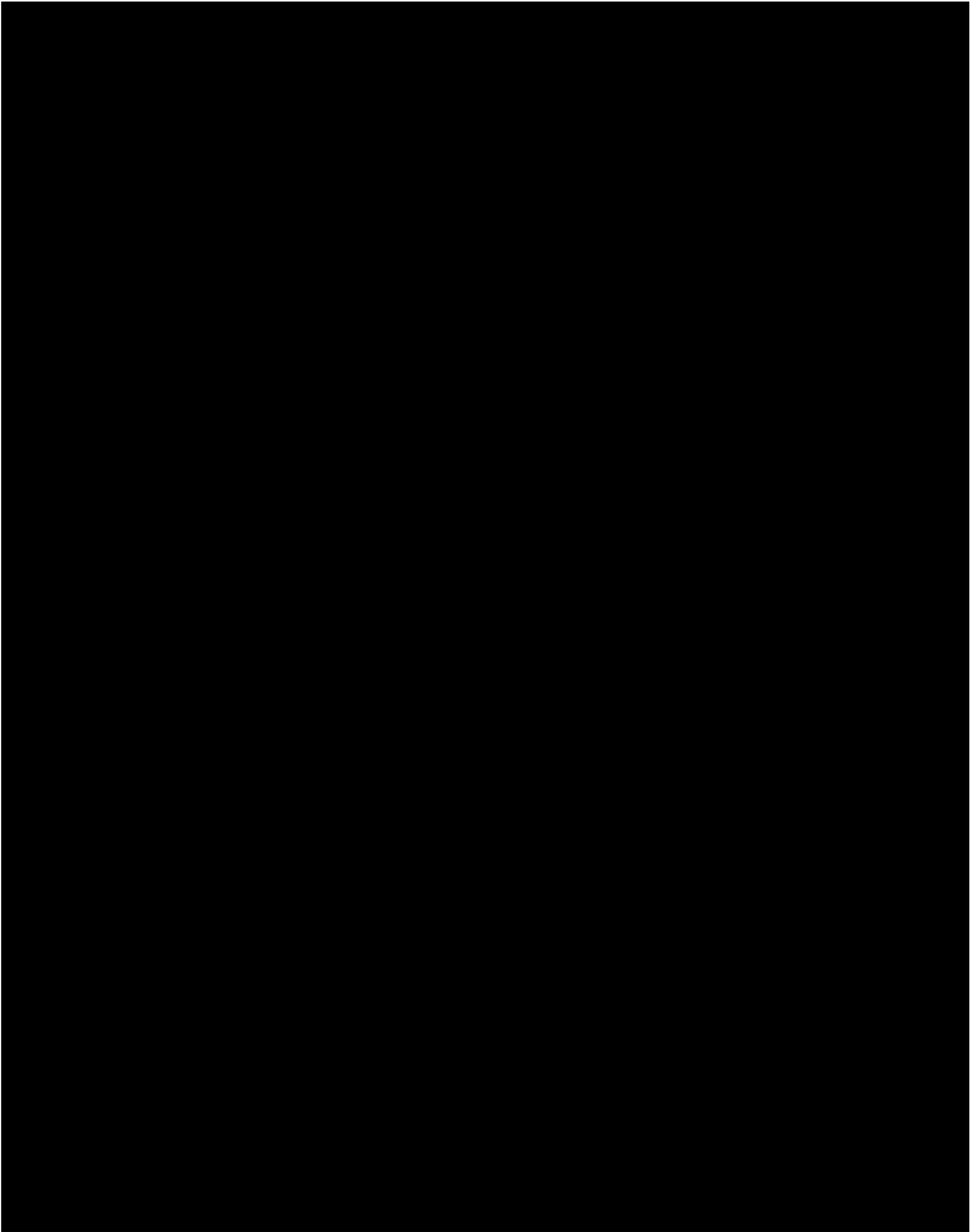


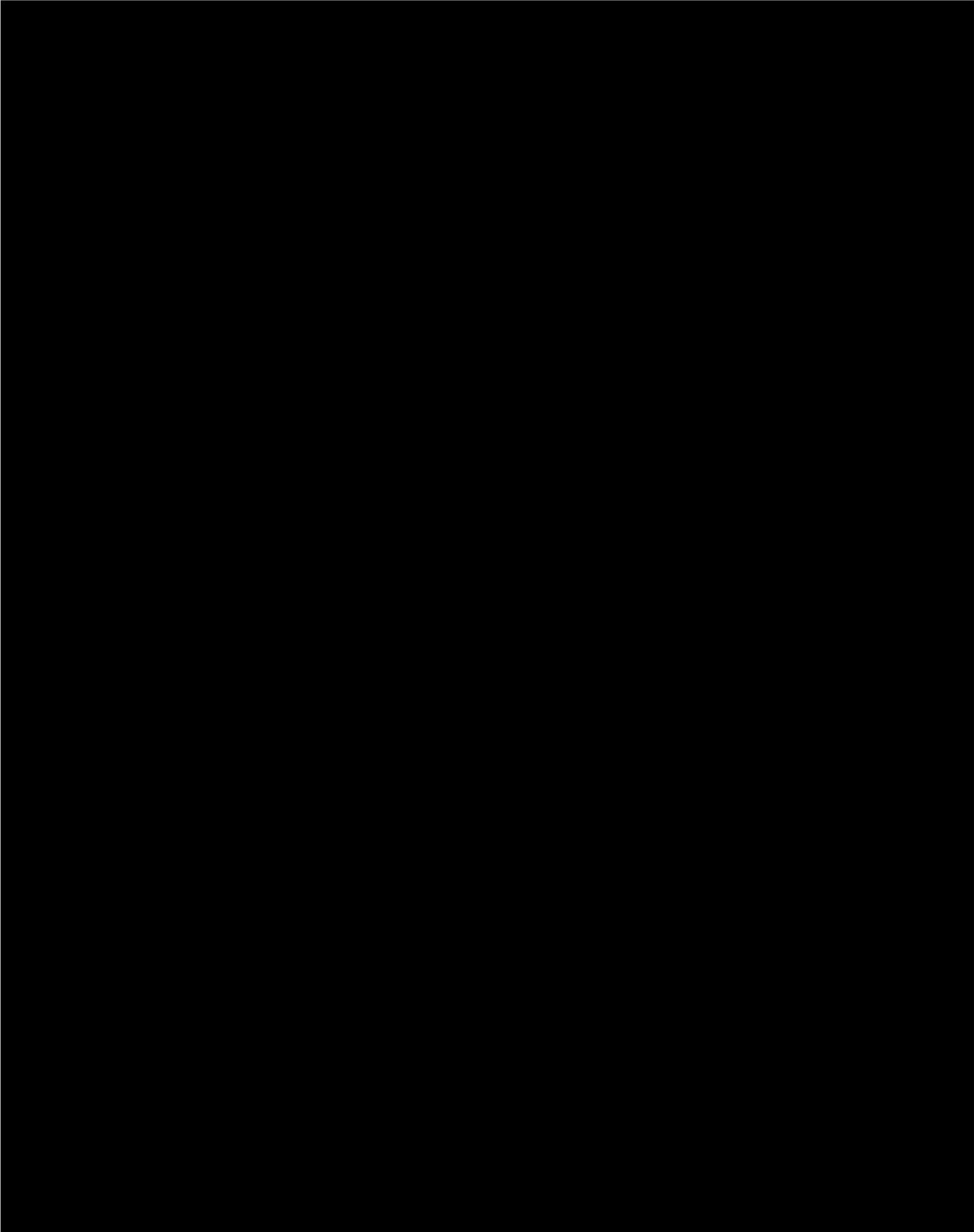


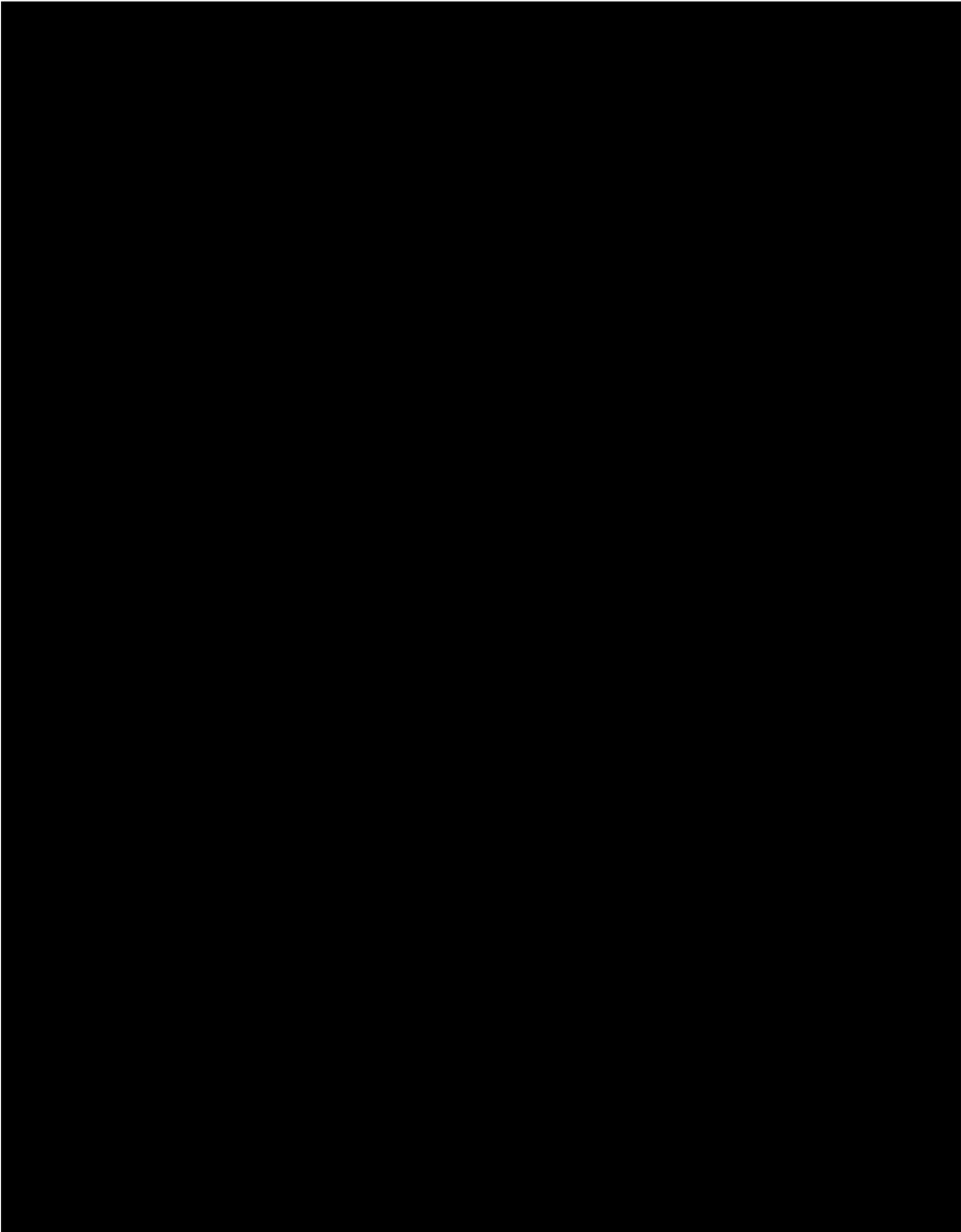


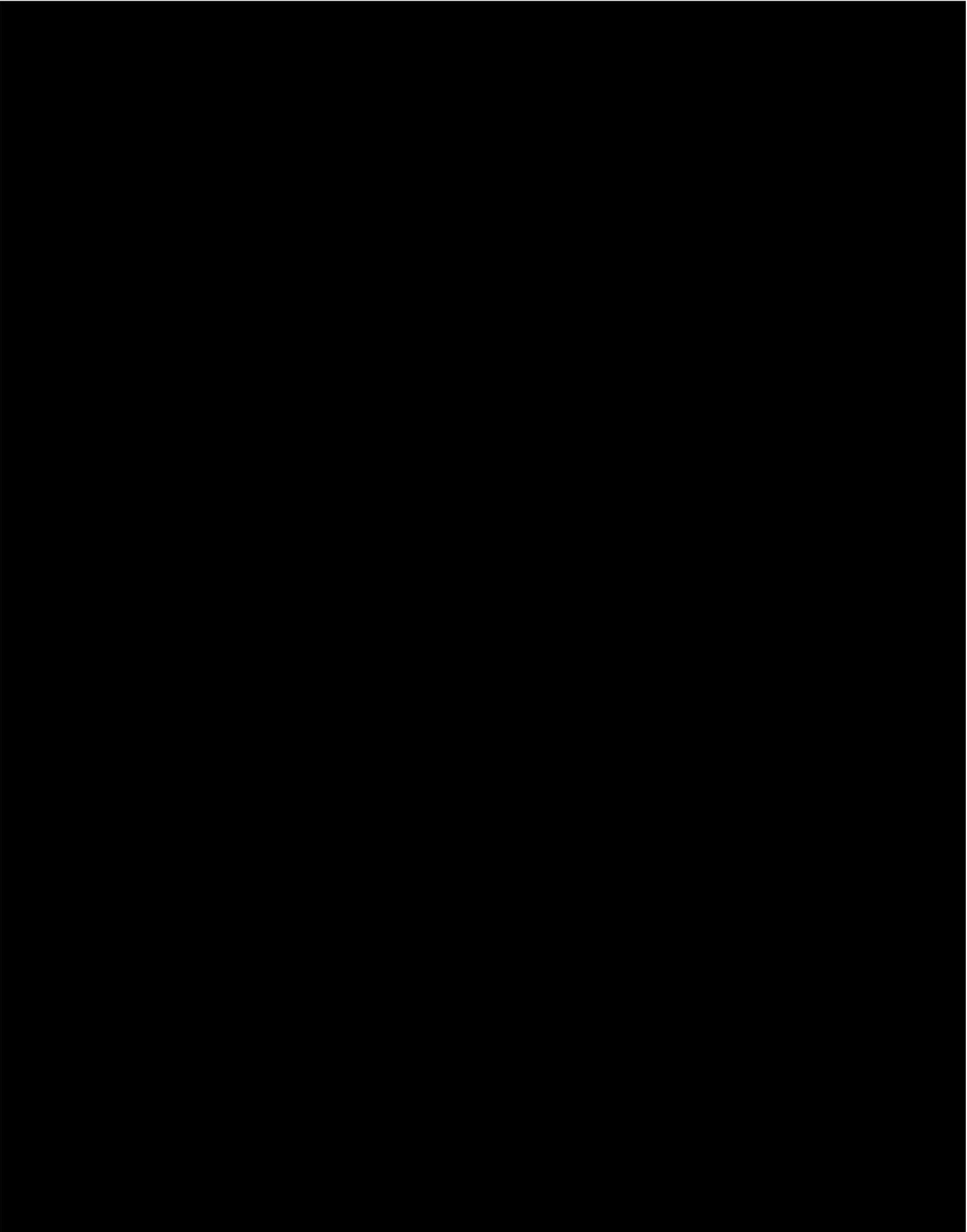


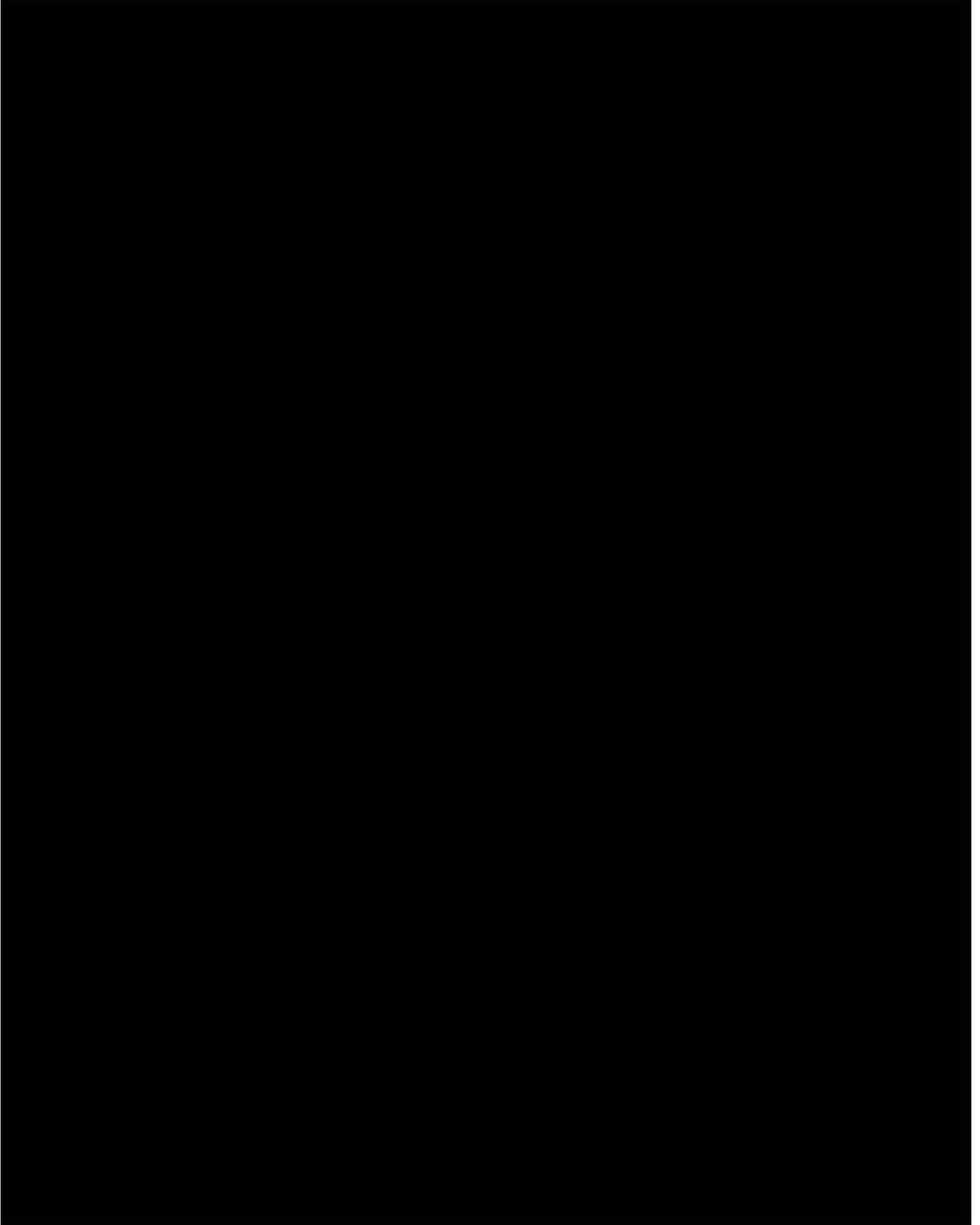


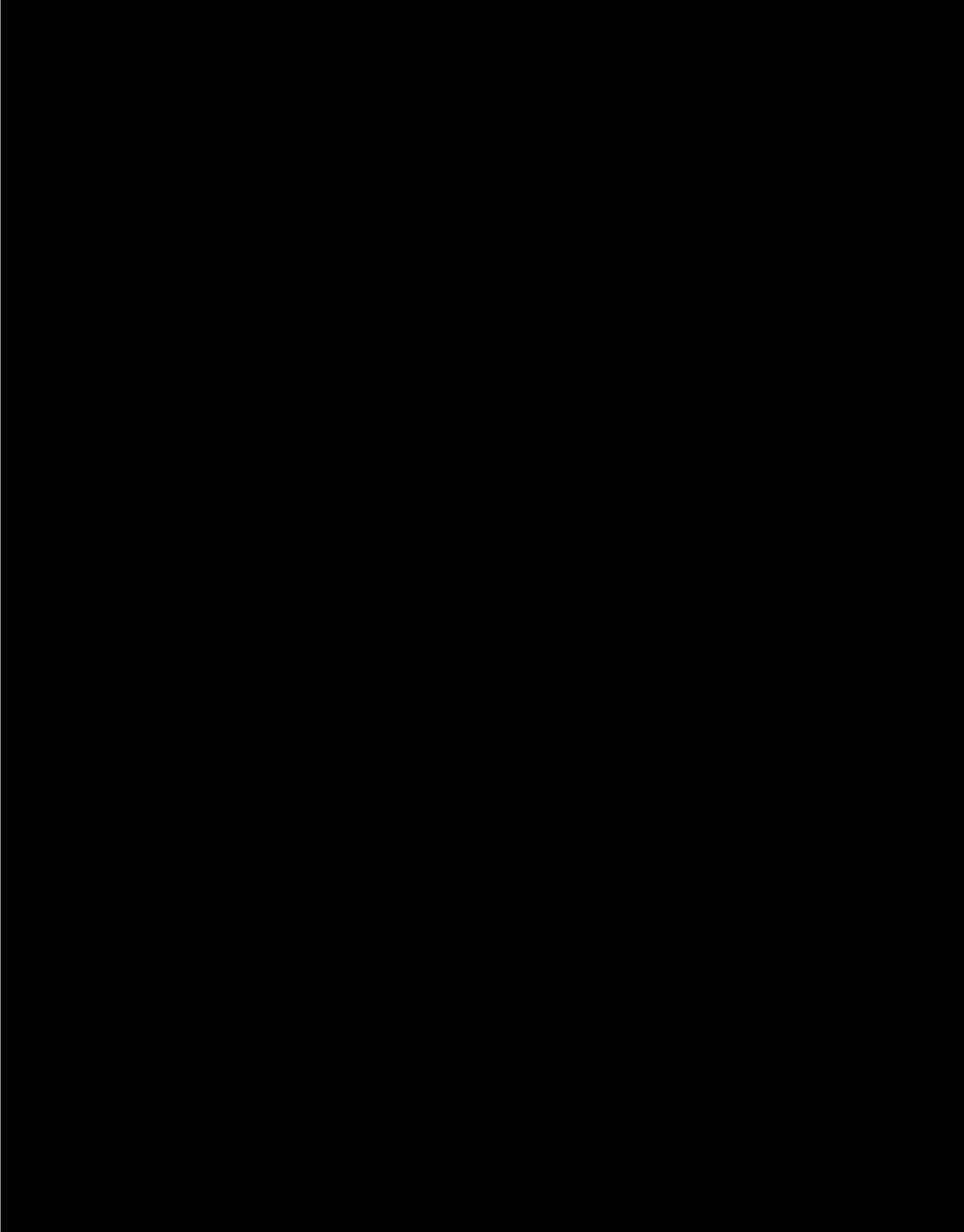


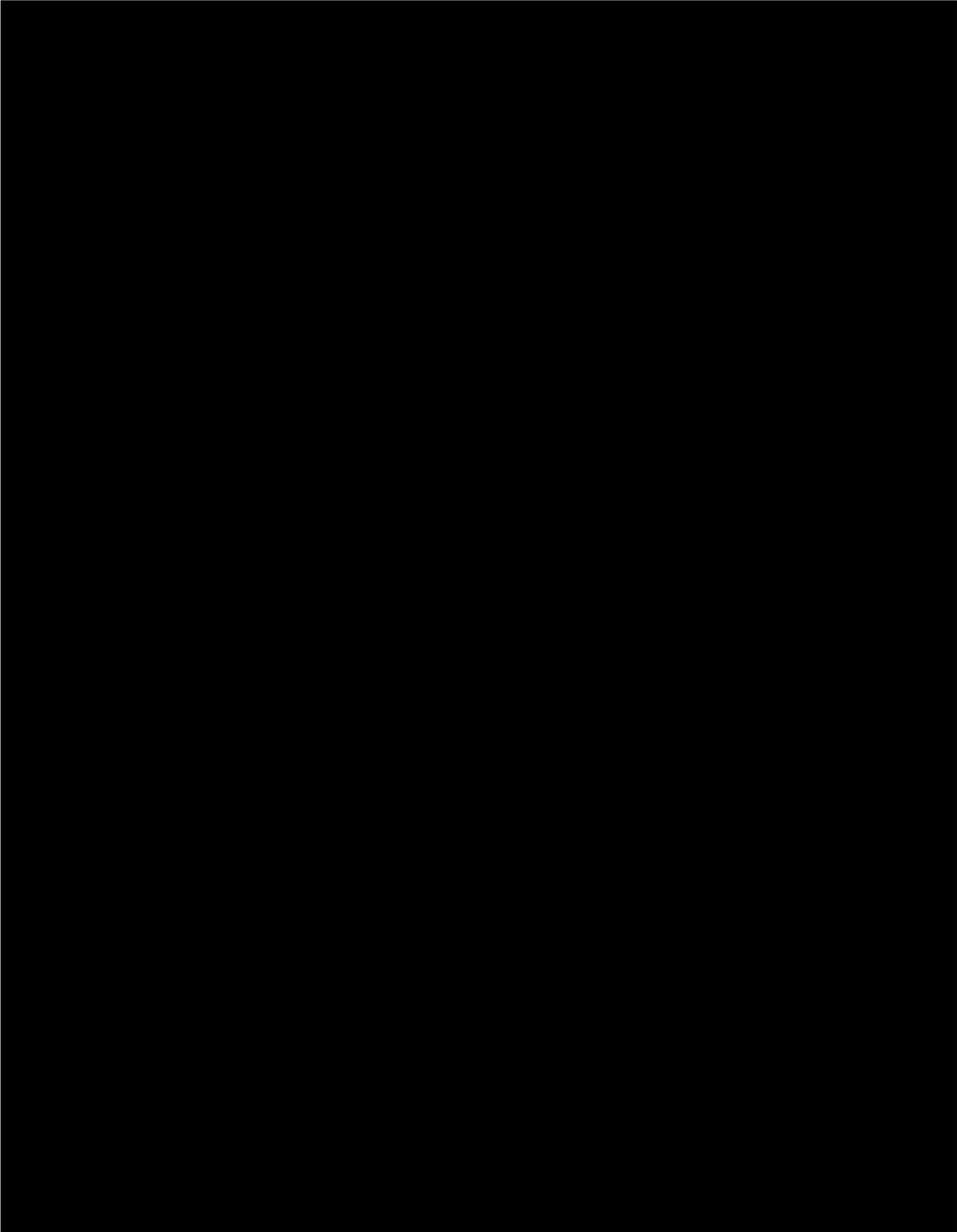


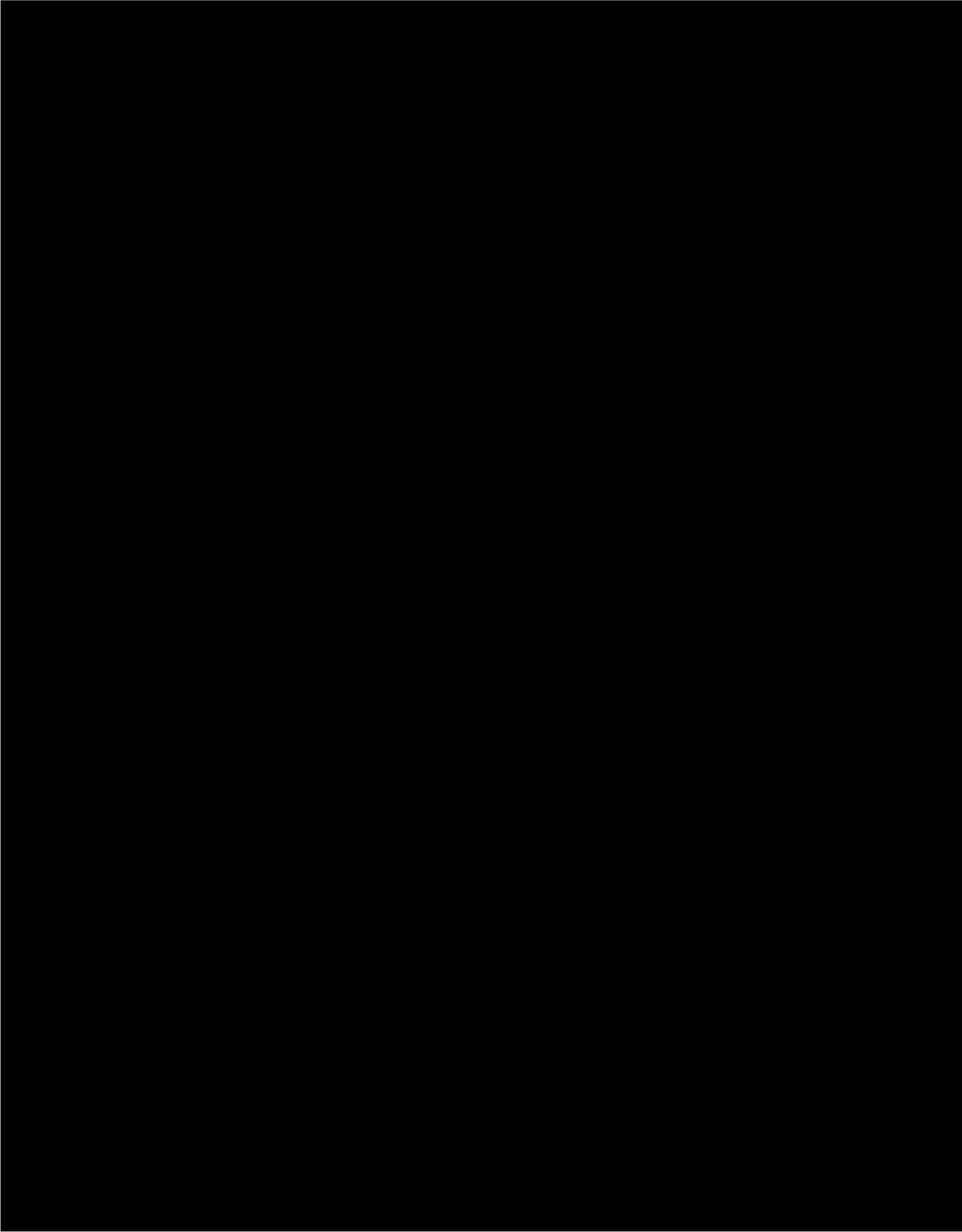


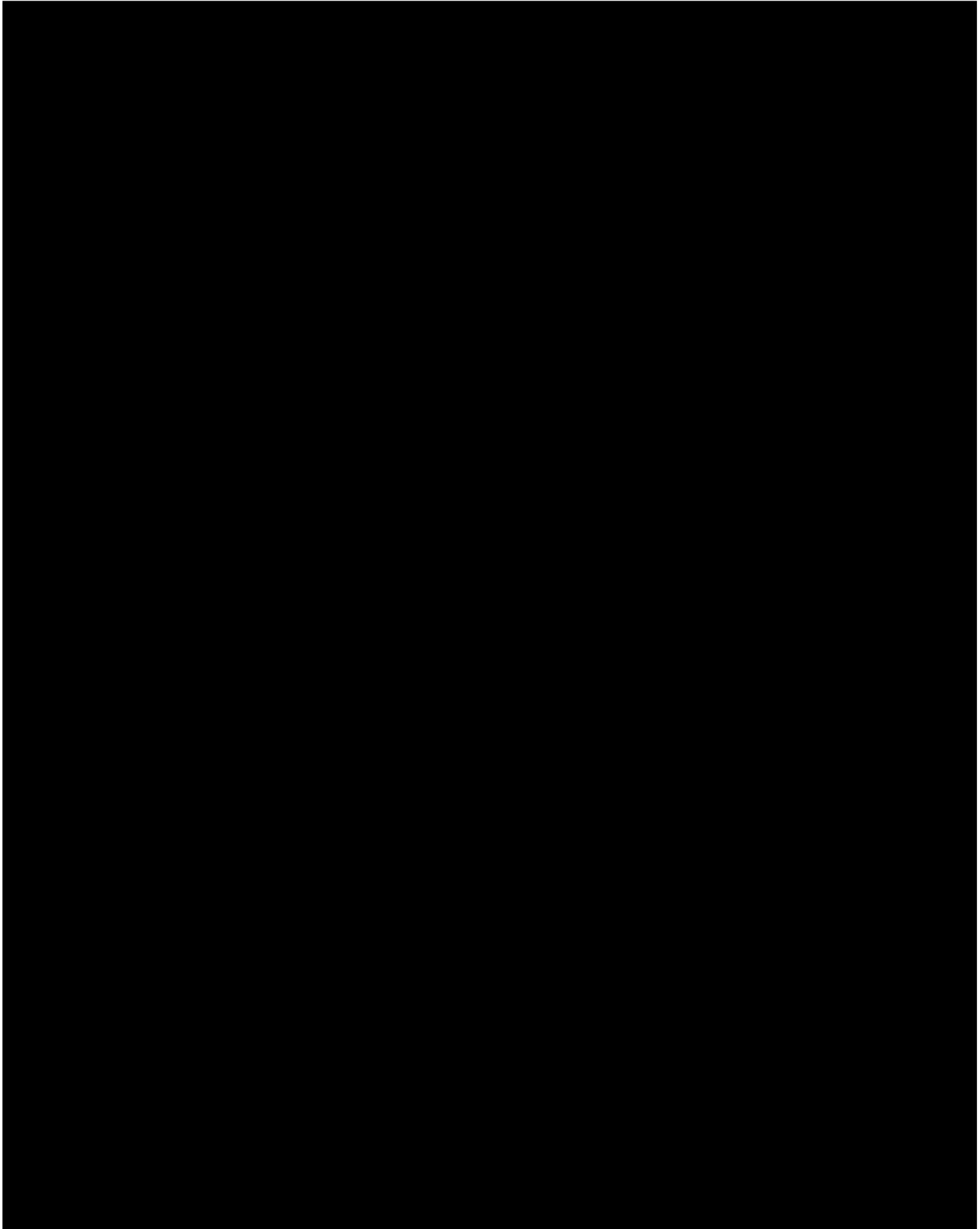


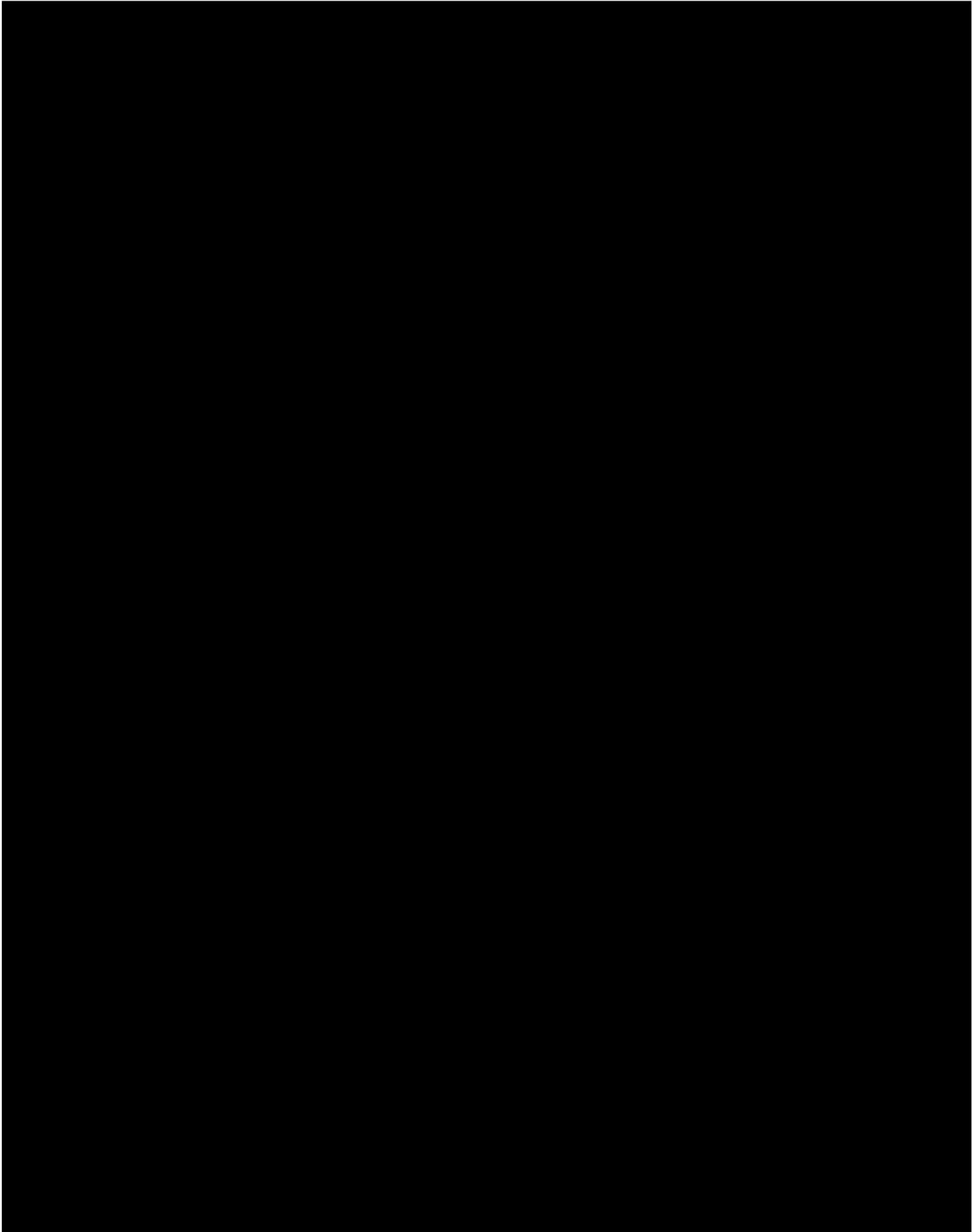


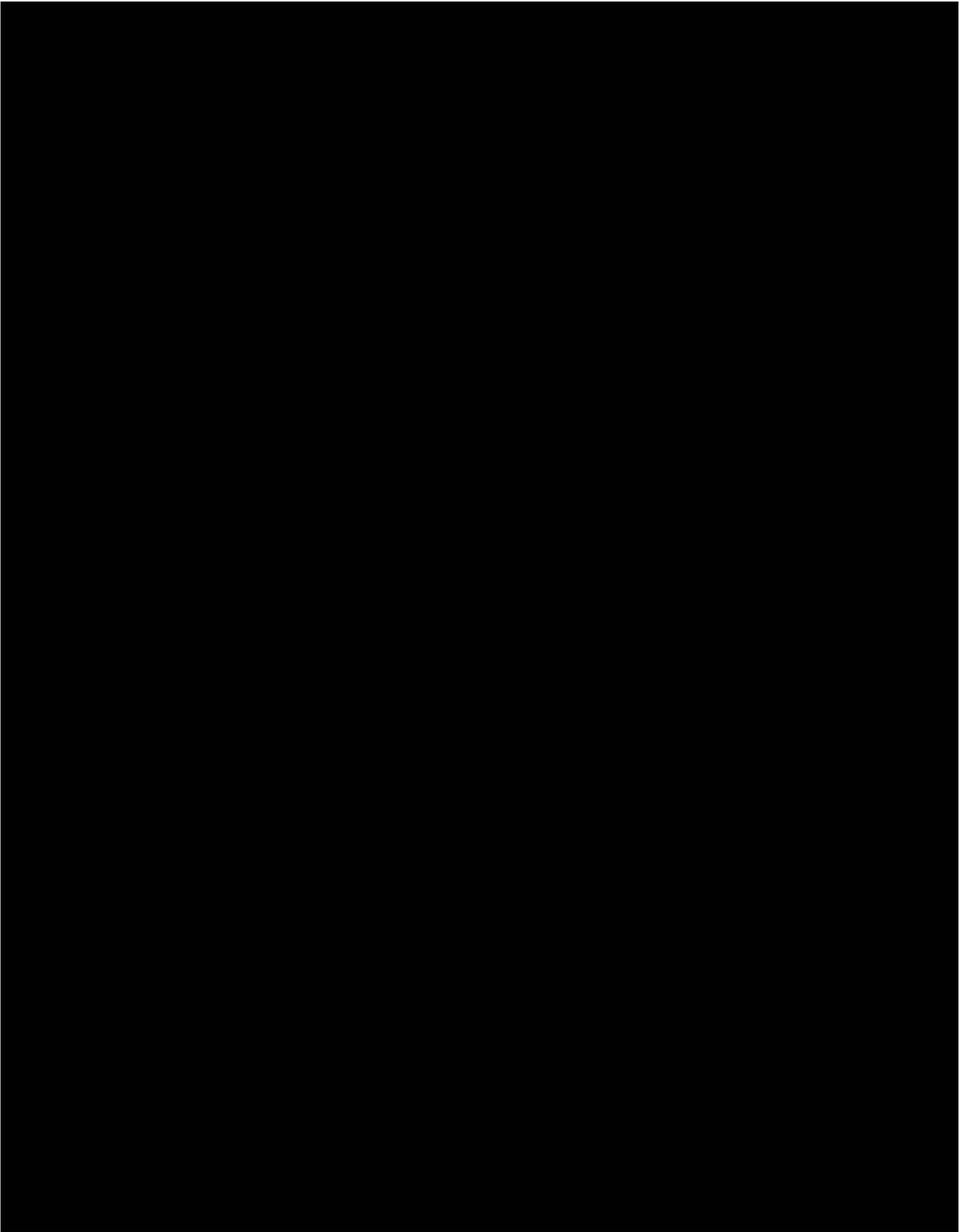


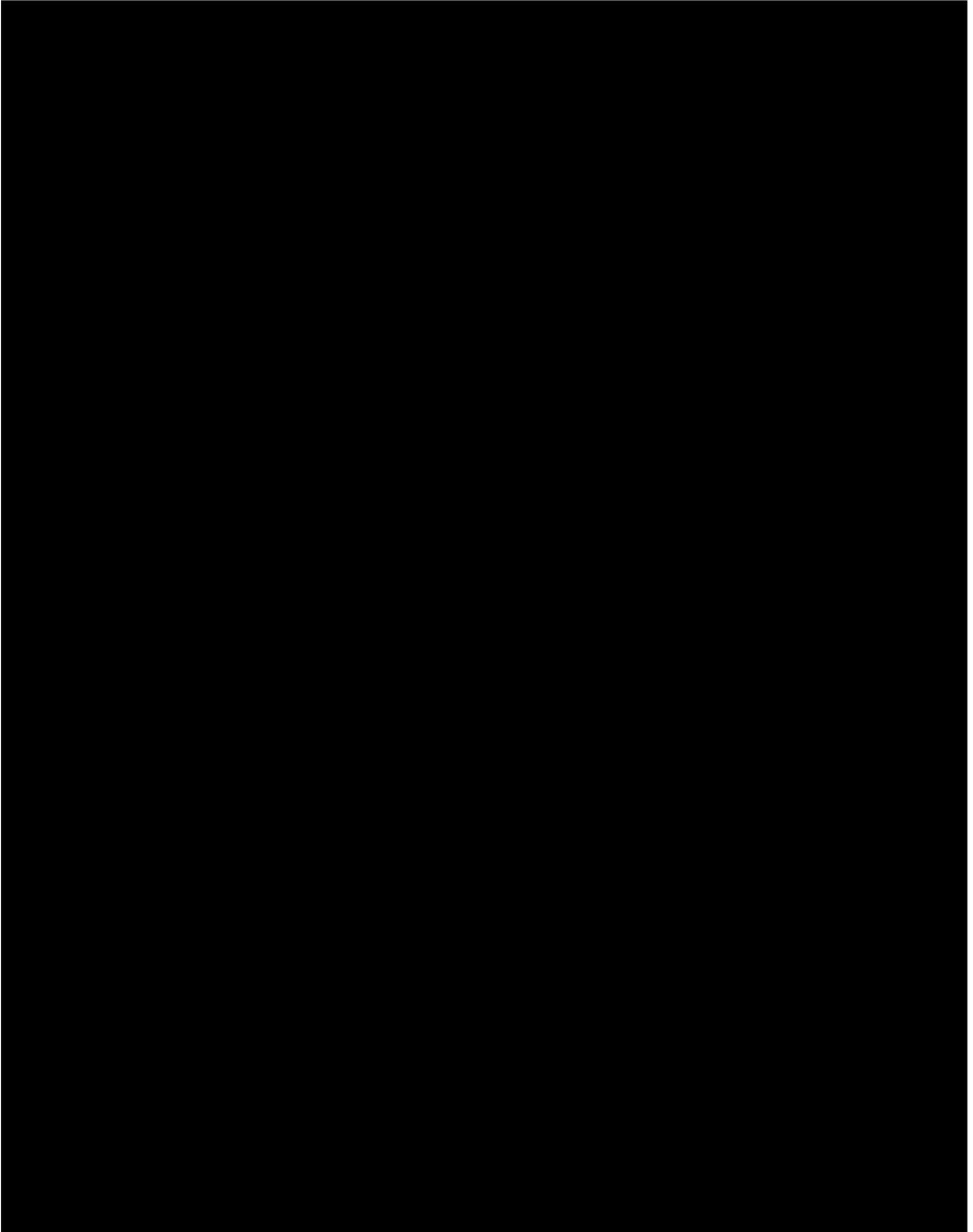


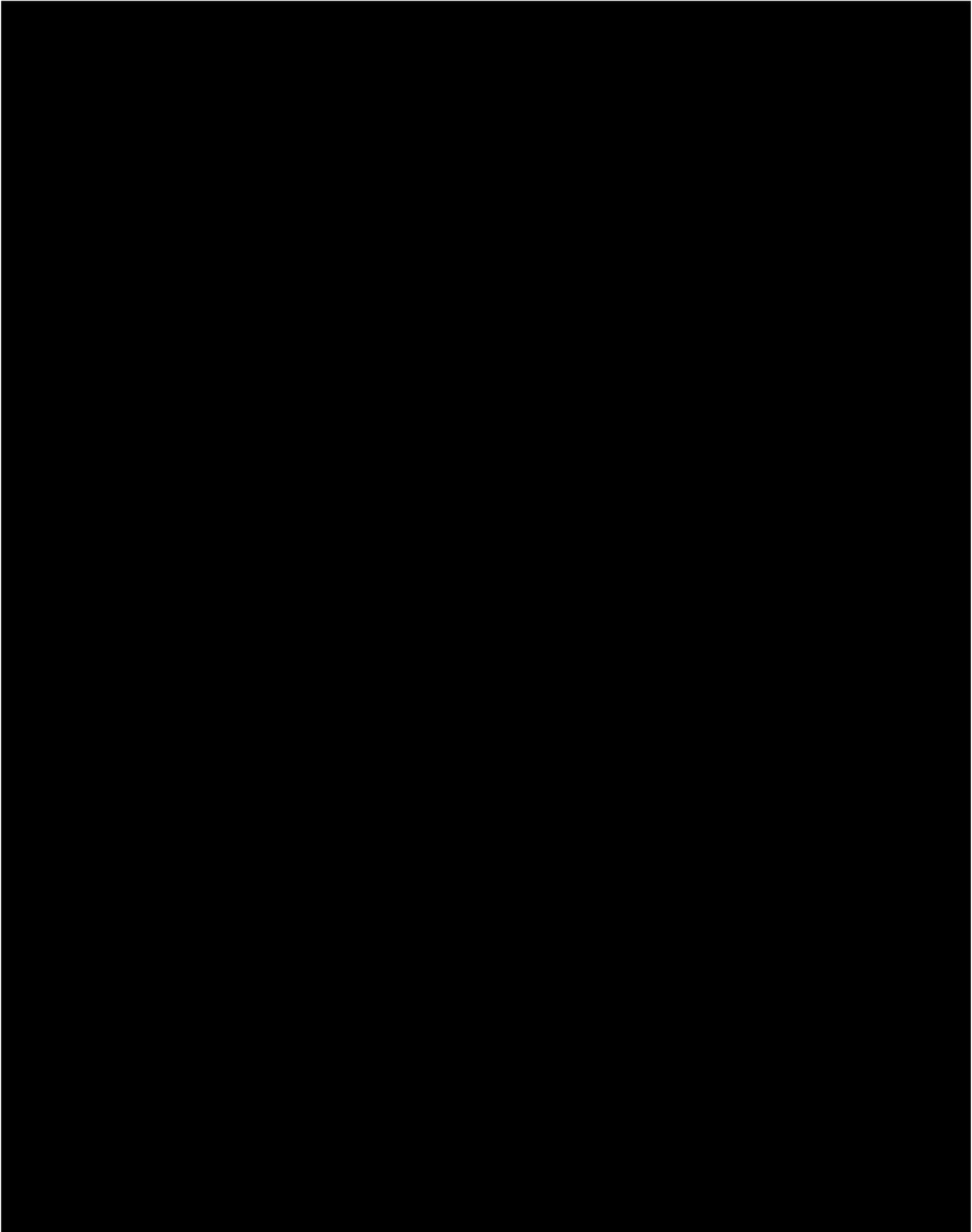


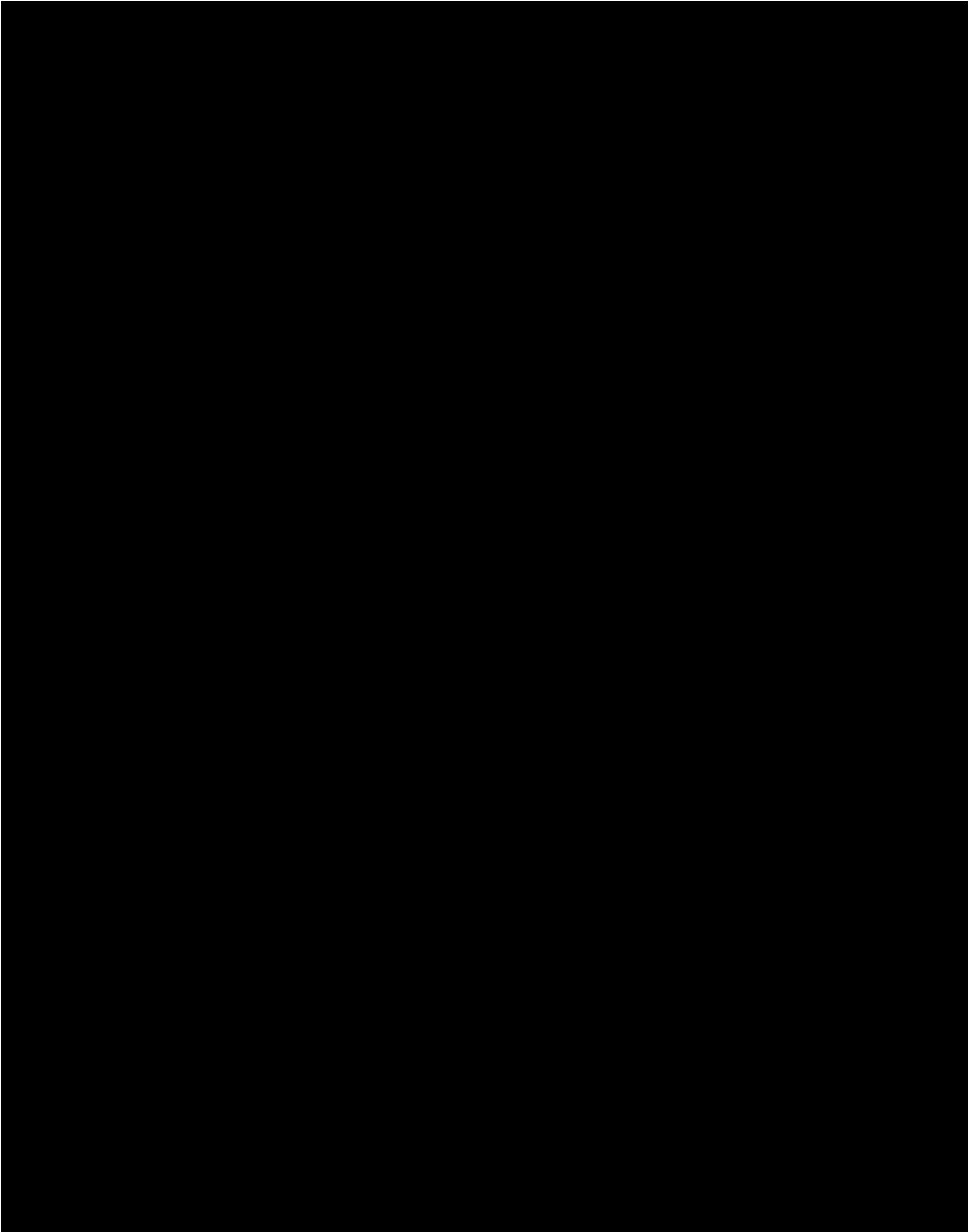


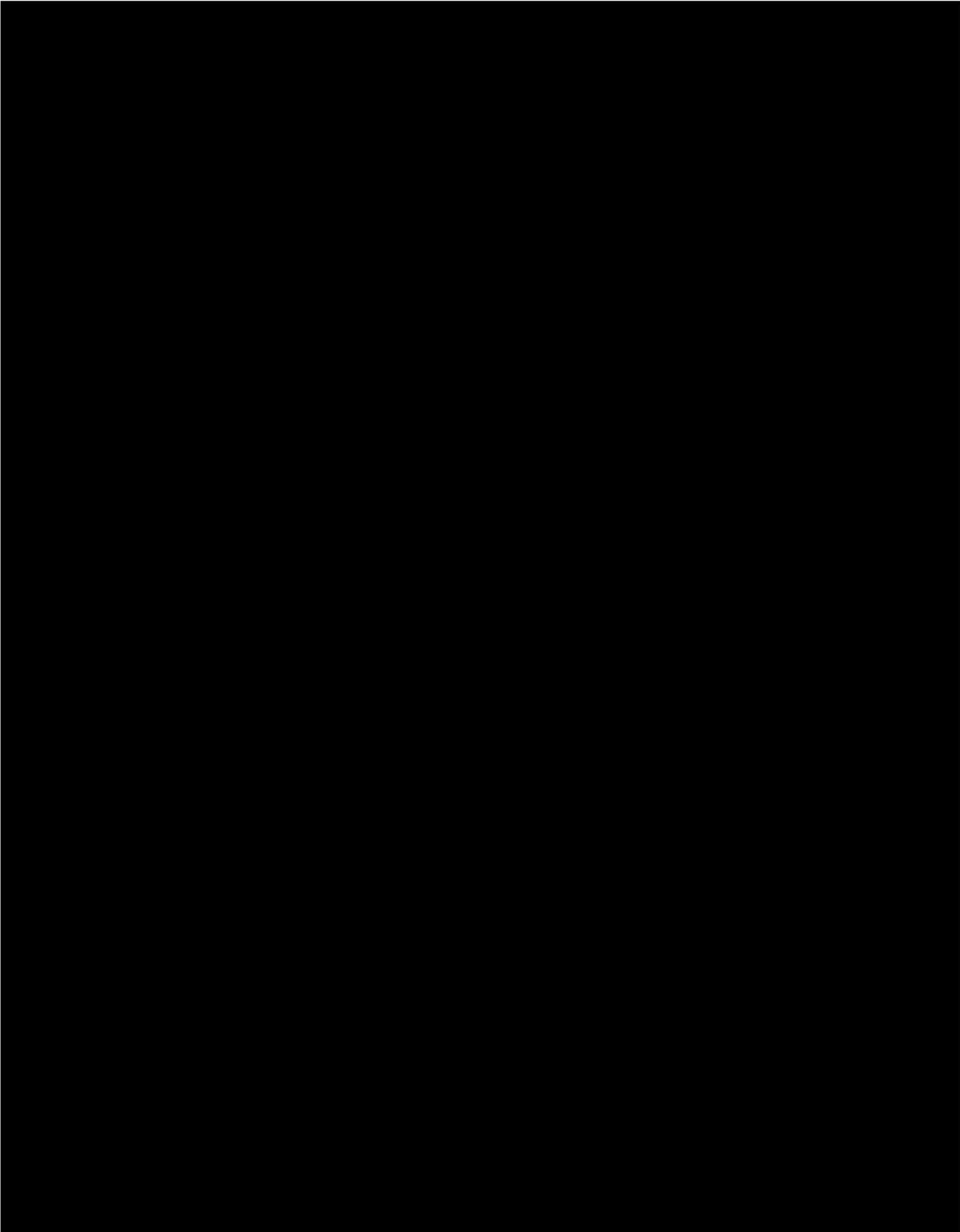


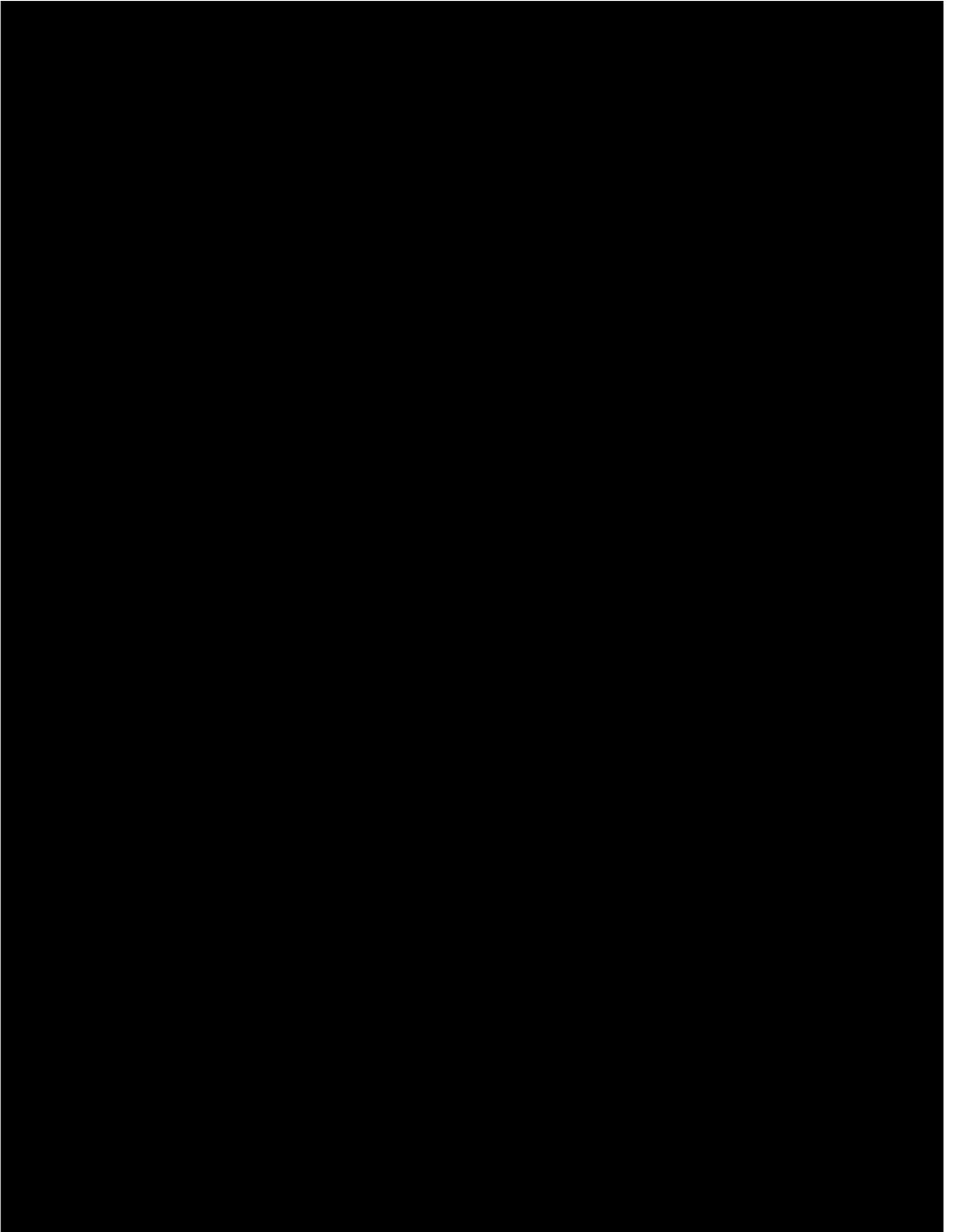


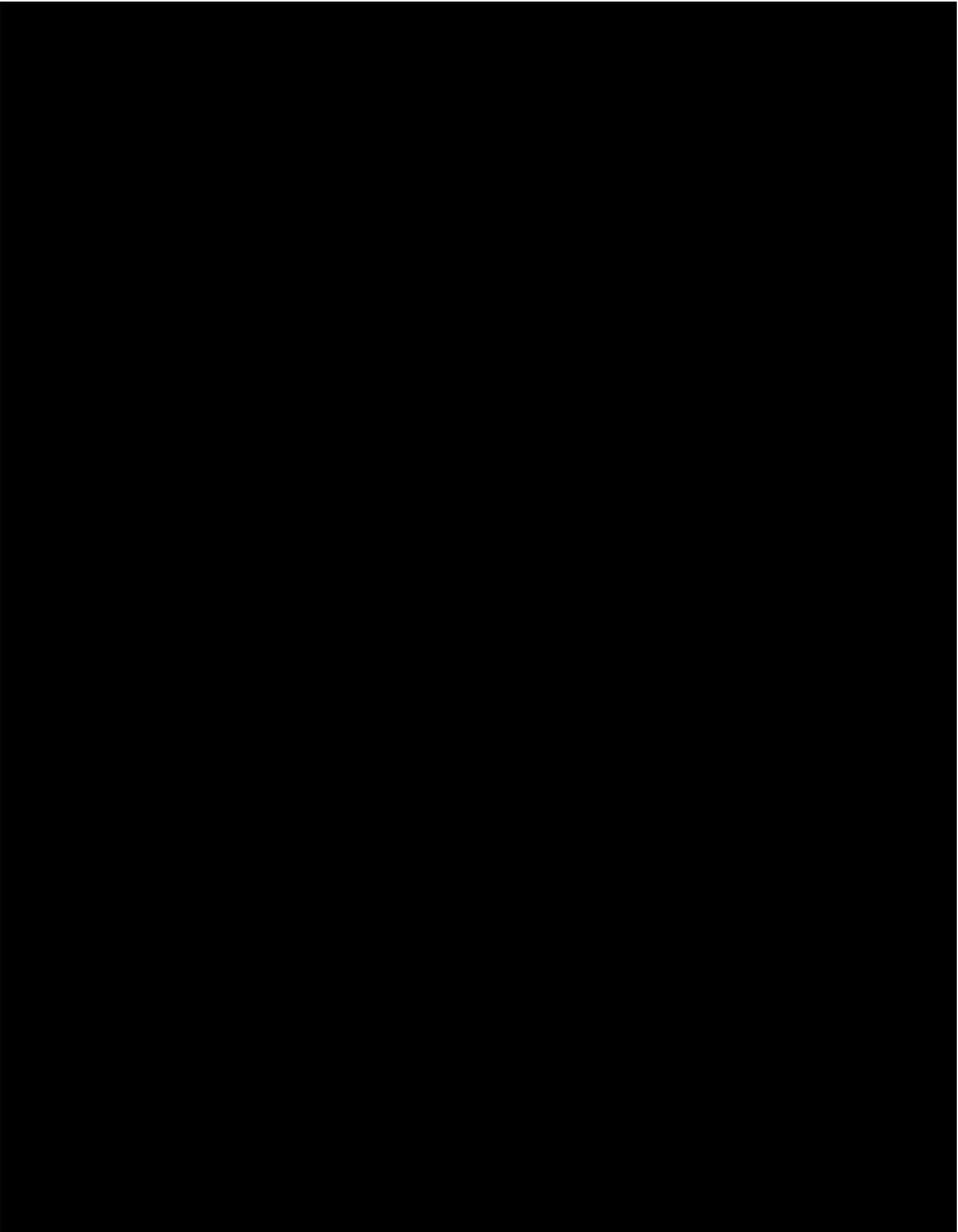












APPLE'S (PROPOSED) REDACTIONS

EXHIBIT 3
[Filed Under Seal]

UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
OAKLAND DIVISION

APPLE IPOD ITUNES ANTI-TRUST
LITIGATION

Lead Case No. C-05-00037-YGR

**SUPPLEMENTAL REBUTTAL DECLARATION OF
ROGER G. NOLL ON LIABILITY AND DAMAGES**

My name is Roger G. Noll, and previously I have submitted nine declarations in this proceeding.¹ My previous declarations contain my career history and qualifications.

ASSIGNMENT AND SUMMARY

Attorneys for the class plaintiffs in this litigation have asked me to review the *Supplemental Report of Kevin M. Murphy and Robert H. Topel* (December 20, 2013, henceforth *Joint Report*) to determine if anything in this report causes me to alter any of the opinions I expressed in either the *Noll Merits Report* or the *Noll Merits Rebuttal*.

The answer to this question is simple. The *Joint Report* contains no new arguments and no valid new data analysis, so nothing in that report requires me to change any of my analysis or conclusions.

¹ *Declaration of Roger G. Noll* (July 15, 2008), *Reply Declaration of Roger G. Noll* (October 19, 2009), *Declaration of Roger G. Noll* (January 18, 2011), *Reply Declaration of Roger G. Noll* (March 28, 2011), *Supplemental Declaration of Roger G. Noll* (July 18, 2011), *Second Supplemental Declaration of Roger G. Noll* (September 23, 2011), *Declaration of Roger G. Noll on Liability and Damages* (April 13, 2013, henceforth *Noll Merits Report*), *Corrections to the Declaration of Roger G. Noll on Liability and Damages* (May 13, 2013), and *Rebuttal Declaration of Roger G. Noll on Liability and Damages* (November 25, 2013, henceforth *Noll Merits Rebuttal*).

The *Joint Report* perpetuates econometric mistakes that Professors Murphy and Topel have made in prior reports. These mistakes are as follows. (1) The assertion that the regression in the *Noll Merits Rebuttal* must be corrected to account for clustering effects. (2) The claim that more independent variables should be added to a regression equation if they add any explanatory power, even if these variables are highly collinear with other variables in the equation. Repeated assertion does not make an incorrect econometric argument correct, and Professors Murphy and Topel remain misinformed about the appropriate econometric technique for estimating a reliable hedonic price equation from Apple's iPod transactions data.

The *Joint Report* claims that correlation among the residual errors when iPod transaction data are grouped by quarters implies that the coefficients in the hedonic price regressions in my prior reports suffer from a clustering problem that causes the results to be unreliable. This claim remains false. The method that Professors Murphy and Topel use to detect autocorrelation among the residuals remains just as incorrect as it was in prior reports by defendant's experts.

The method that defendant's experts use to "correct" for this problem remains just as incorrect as it was previously. Their method is equivalent to replacing observations on transactions prices with quarterly average prices. The main effect of this procedure is vastly to reduce the precision of the regression equation, thereby causing the coefficients of the iTunes 7.0 variables to become insignificant. Because Professors Murphy and Topel have no valid reason for picking calendar quarters as the basis for creating clusters, these results are meaningless. Indeed, if one adopts a week as the time period for creating clusters, which also shows non-zero mean residual errors by family/week, the

coefficient on the iTunes 7.0 variable is again significant for direct sales. Professors Murphy and Topel have no basis for picking calendar quarters over weeks as the basis for creating groups of observations, and so no reason to prefer their results to results from a shorter time period.

The *Joint Report* continues to insist that the indicator variable for iTunes 4.7 should remain “on” for the iPod models that included iTunes 7.0, and adds the argument that the new treatment of iTunes 7.0 is inconsistent with my former testimony. Defendant’s experts give no new reason for leaving iTunes 4.7 turned “on” for models that did not include iTunes 4.7 after the introduction of iTunes 7.0.

CLUSTERING

The *Joint Report* repeats the argument that the error terms in my regressions are correlated within “clusters” (iPod product families in a quarter).² As a baseline matter, there is no clustering problem among iPod transactions. As explained by Professor Wooldridge, clustering problems occur when data are drawn from a sample of a population of groups, or clusters.³ Professors Murphy and Topel are guilty of **ex post** clustering, which occurs when groups in either a sample or a population are identified as belonging to a certain group, which is then after-the-fact labeled a cluster.⁴

² *Joint Report*, pp. 4-5.

³ *Declaration of Jeffrey M. Wooldridge in Support of Plaintiff’s Daubert Motion to Exclude Certain Opinion Testimony of Robert H. Topel and Kevin M. Murphy* (henceforth, *Wooldridge Declaration*), December 20, 2013, p. 3.

⁴ *Wooldridge Declaration* p. 3. At his deposition, Professor Wooldridge highlighted the issue of ex post clustering in the context of estimating the average hourly wage from a random sample of data. He indicates that there are many ways to cluster such data (e.g., by occupation or by education level), but none is correct if the underlying data have been gathered randomly so there is no cluster sample. *Deposition of Jeffrey Wooldridge*, p. 40.

In a footnote⁵ Professors Murphy and Topel assert that there is nothing to suggest that clustering is limited to samples, and cite one of the references that I quoted in the *Noll Rebuttal*. This statement is incorrect and misleading.

First, in the chapter of the book by Professors Angrist and Pischke that I cited, the cluster example that the authors use is the STAR experiment, which was based on a sample of classrooms (the clusters are classes). Footnote 10 of this chapter explains that “most of the *samples* [emphasis added] that we work with are close enough to random that we typically worry more about the dependence due to group structure [a reference to excluded independent variables that are correlated with groups] than clustering due to stratification.”⁶ These authors also state, in reference to their whimsical statement that one can stop worrying about cluster effects when the number of clusters is 42 or more: “If 42 is enough for the standard cluster adjustment to be reliable, and if less is too few, then what should you do when the cluster count is low? ***First best is to get more clusters by collecting more data*** (emphasis added).”⁷ Getting more clusters makes sense only if the original number of clusters is less than the population of clusters. In short, the chapter on cluster analysis in the book by Professors Angrist and Pischke is about problems arising from cluster samples. To suggest otherwise is misleading.

Second, all of the other references that I cited in past reports refer to cluster samples. The fact that Professors Angrist and Pischke did not make extensive use of the word “sample” does not imply that cluster effects are not a sampling problem. Thus, the

⁵ *Joint Report*, footnote 21, p. 7.

⁶ Joshua D. Angrist and Jörn-Steffen Pischke, *Mostly Harmless Econometric: An Empiricists Companion*, Chapter 8, Princeton University Press, 2009, p. 309.

⁷ *Ibid*, pp. 319-20.

claim in the *Joint Report* that clustering is *not* related to sampling errors is simply false.

Professors Murphy and Topel motivate their assertion that the iPod transactions data exhibit a clustering problem by presenting a correlation analysis of residual errors. Professors Murphy and Topel calculate the estimated residual for each transaction in each data set (reseller or direct sales), and group these residual errors into families of iPods in each quarter. For this procedure to make sense, some unobserved variable must be present that affects prices in a family of iPods differently in different quarters. Professors Murphy and Topel do not explain what this variable might be, or why the appropriate time period is a calendar quarter, rather than a day, a week, or a year. In short, their choice of calendar quarters as the basis for dividing the data into clusters is arbitrary.

After creating these unmotivated quarterly groups of residual errors by family, Professors Murphy and Topel divide the residuals into two equal-size groups within each product family/quarter group, calculate the average residual within each half, and plot the mean residuals from each group against each other (Exhibits JT-4a and JT-4b of the *Joint Report*). According to Professors Murphy and Topel, these graphs demonstrate that the residual errors are correlated.

Professor Murphy's and Professor Topel's analysis is unreliable because the groups into which they divide the observations are artificially created. The specification of the price regressions guarantees that each combination of class and capacity of an iPod will have a mean residual error of zero. If one then divides these residual errors into time periods, the mean errors of these groups taken together still will be zero, but as a statistical matter the mean residual errors for every such group is not expected to be zero. Instead, the values of the mean residual errors among the groups will be randomly

distributed around zero, with some values above zero and some below.

To demonstrate that the results in the *Joint Report* have nothing to do with whether a calendar quarter is somehow an appropriate basis for clustering the data, the procedures that were used in the *Joint Report* were applied to two other ways to divide the data by time period: by family/month and by family/week. The results of these alternate specifications are shown in Exhibits 1a-b and 2a-b, and are qualitatively identical to the family/quarter results in the *Joint Report*.⁸ As Exhibits 1a-b and 2a-b show, using the same method that Professors Murphy and Topel use, residuals also are correlated among these smaller groups. This is exactly the result one would expect. A similar result would be observed if one plotted mean residual errors for each family/year or family/day, or any other time period short of the full data period.

These results show that there is no basis in the correlation analysis for picking quarterly data as the hypothetical clusters, as opposed to weekly or monthly data, or even daily or yearly data. The correlations of residual errors are not due to the standard problem of cluster samples – the presence of unobserved variables that affect outcomes differentially among the groups – but are the expected result of dividing the residual errors into a large number of arbitrarily selected groups.

The *Joint Report* “corrects” the non-existent clustering problem by grouping the transactions data by quarter. This procedure is equivalent to vastly reducing the number of observations in the regression, thereby vastly reducing the degrees of freedom and vastly increasing the standard errors of the regression coefficients. Choosing ex-post clusters by time period at any level of granularity is purely ad hoc. A family/quarter

⁸ Exhibits 1a (monthly) and 2a (weekly) show the results from the regression on the reseller data, while 1b and 2b show the results from the direct sales regression.

cluster has the convenient effect that it causes the coefficients in the regression equation to become insignificant and the estimated damages to be zero. But Professors Murphy and Topel could have chosen any time period, from a day to a year, on the basis of the same procedure that they used to test for correlation of the residual errors. Professor Murphy asserts that clusters probably should be defined more broadly than quarters, but the results of the correlation analysis, which are the only basis for the clusters that Professor Murphy selected, provide no support for this assertion.⁹

As the duration of the time period into which the data are grouped grows shorter, (e.g., by weeks instead of months, or months instead of quarters), the effective number of observations increases and so the standard errors of the regression coefficients become smaller. The number of clusters also increases, which, as Professors Angrist and Pischke state, makes the clustering problem (if it exists) become less important. For example, if the direct sales regression in my rebuttal report is grouped by family/week, the coefficient on the iTunes 7.0 variable of interest becomes statistically significant.¹⁰ If one defined ex post clusters even more finely, the standard errors of coefficient on iTunes 7.0 would fall still more. Of course, it is just as incorrect to define clusters by week as by quarter—all are ad hoc constructs. The proper approach is no clustering at all.

MULTICOLLINEARITY

The *Joint Report* criticizes the regressions in the *Noll Merits Rebuttal* for omitting

⁹ See, e.g., *Deposition of Kevin M. Murphy*, January 8, 2014 (rough transcript), pp. 26-27. Also see *Deposition of Kevin M. Murphy*, November 12, 2013, pp. 125-129.



variables that measure attributes of iPods that they believe are expected to affect iPod prices. The *Noll Merits Rebuttal* (p. 8) explains that adding these attributes causes multicollinearity, which causes the standard errors of the regression coefficients to be unreliable. The *Joint Report* repeats this claim, and asserts that I have done nothing to determine whether adding any additional characteristics would cause extreme multicollinearity¹¹ and that adding the selected iPod attributes does not cause a multicollinearity problem.¹² Both claims are incorrect.

As explained in the *Noll Rebuttal* (p. 31),

The problem that multicollinearity creates is to reduce the precision of the estimated coefficients in the regression, making them less reliable as estimates of the true effect of an independent variable on the dependent variable. Thus, the effect of piling on more iPod characteristics that add no explanatory power to the hedonic regression is to cause all of the estimated coefficients, including the coefficient on iTunes 7.0, to become less reliably estimated.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Because the regressions in the *Noll Merits Rebuttal*

¹¹ *Joint Report* p. 10.

¹² *Joint Report* p. 12.

[REDACTED]

include a large number of product characteristics that affect iPod prices, regressions with any additional product attributes should be tested for multicollinearity. Professors Murphy and Topel did not do so in either their original merits reports or the *Joint Report*. The adjusted R^2 , “variance inflation factor” (VIF) and “condition number”, explained below, are statistics that indicate when multicollinearity is likely to cause coefficients of a regression model to be inaccurate and imprecisely measured.¹⁴ Professors Murphy and Topel did not consider these statistics, and the statistics they do report are misleading.

Professors Murphy and Topel assert four justifications for including the additional iPod attributes in the regressions (paragraph references are to the *Joint Report*):

1. With one or two exceptions (depending on the regression) the additional iPod attributes are individually statistically significant (¶17).
2. The additional iPod attributes are jointly significant (¶17).
3. The additional iPod attributes increase the R^2 of the reseller and direct sales regressions, and not by a “small” amount (¶18).
4. Including the additional product attributes does not substantially increase the estimated standard error of the iTunes 7.0 coefficient, as would occur if the iTunes 7.0 variable were affected by multicollinearity. (¶21).

Professors Murphy and Topel do not explain how the first three statements justify ignoring the problem multicollinearity should it exist. Even if variables are individually or jointly significant and add to the explanatory power of a regression, that alone is insufficient justification to include them in the regression. Defendant’s class certification expert, Dr. Michelle Burtis, showed that events irrelevant to iPod pricing could be statistically significant in a regression model.¹⁵ One needs a reason, derived from economic theory or econometrics, to add variables to a regression, especially if these

Merits Report. See *Deposition of Robert H. Topel*, November 8, 2013, pp. 28-29.

¹⁴ See William H. Greene, *Econometric Analysis* (4th ed.), Prentice Hall 2000, pp. 257-258 for a discussion of collinearity diagnostics.

¹⁵ *Second Supplemental Report of Dr. Michelle M. Burtis*, November 14, 2011, p. 20 and Exhibit 7.

variables create a problem with reliably estimating the equation.

When economic theory provides a reason to believe these variables might be causally related to the dependent variable, if the additional attributes create a multicollinearity problem, the problem must be addressed. The two methods for addressing multicollinearity are to add more data (here not possible because the data are a population, not a sample) and to eliminate one or more collinear variables.

Professors Murphy and Topel assert without proof that the regressions that they ran do not suffer from multicollinearity. Tests for the presence of multicollinearity applied to the models reported in the *Joint Report* (Exhibits JT-3a and JT-3b column 4) show that, in fact, the variables that defendant's experts add to the regression model cause severe multicollinearity.

Three statistical tests are used to detect multicollinearity: adjusted R-squared, condition number, and the variance inflation factor (VIF). The adjusted R-squared test, when used in an "auxiliary" regression of a potentially multicollinear variable on the other explanatory variables in a model, measures correlations among the variables. The condition number measures how sensitive the output of a model is to small changes in data. The VIF measures the severity of multicollinearity in a regression.

All but one of the iPod attributes that Professors Murphy and Topel add to the regressions in the *Noll Merits Rebuttal* generate a multicollinearity problem.¹⁶ Each of the iPod attributes that were added by Professors Murphy and Topel¹⁷ were regressed on

¹⁶ The exception is whether the iPod transaction was an original equipment manufacturer ("OEM") sale to Hewlett-Packard, an attribute applicable to reseller but not direct sale transactions. Hewlett-Packard OEM transactions have a high condition number but low adjusted R² and VIF.

¹⁷ "Model 4" refers to the model reported in column 4 of the *Joint Report* Exhibits JT-3a

the other variables that were included in the regressions in the *Noll Merits Rebuttal*. The adjusted R^2 , condition number, and VIF from each of these “auxiliary” regressions is reported in Exhibit 3 and Exhibit 4. If the R^2 from an auxiliary regression is high and similar to the R^2 of the main equation to be estimated, then multicollinearity is severe.¹⁸ The R^2 's in the regressions in the *Joint Report* are 0.9930 (resellers) and 0.9866 (direct sales). As shown in Exhibits 3 and 4, the R^2 's from auxiliary regressions for all of the additional product attributes are highly similar to the R^2 of the main equation to be estimated. The lowest R^2 among auxiliary regressions in the reseller data (Exhibit 3) is 0.9767 (recharge hours). The lowest R^2 among auxiliary regressions in the direct sales data (Exhibit 4) is 0.9728 (recharge hours).

The condition number associated with each auxiliary regression indicates when the coefficient estimates in the underlying regression are likely to be affected by multicollinearity.¹⁹ A condition number exceeding 10 in a model with a large number of independent variables is regarded as indicating that multicollinearity is likely to be a serious problem.²⁰ The smallest condition number in Exhibits 3 and 4 is 1548. These

and JT-3b. This model includes the additional iPod attributes. I previously performed a similar analysis using the models in the initial *Murphy Report* and *Topel Report* with the difference that each auxiliary regression included only the explanatory variables in the *Noll Merits Report* and not the other product attributes added by Professors Murphy and Topel. Results were similar.

¹⁸ Klein, L., *An Introduction to Economics*, Prentice-Hall (1962), as reported in Greene *op cit.* p. 258.

¹⁹ Greene p. 258 and SAS v 9.3 documentation (http://support.sas.com/documentation/cdl/en/statug/63962/HTML/default/viewer.htm#statug_reg_sect036.htm).

²⁰ The condition number is not a reliable indicator of serious multicollinearity when the number of independent variables is very small (two or three). See Alexis Lazaridis, “A Note Regarding The Condition Number: The Case of Spurious and Latent Multicollinearity,” *Quality and Quantity* Vol. 41, No. 1 (February 2007), pp. 123-35.

statistics indicate that each of the additional product attributes generates multicollinearity problems in the underlying reseller or direct sales regression.

The VIF of each auxiliary regression is equal to $1/(1-R_k^2)$, where R_k^2 is the R^2 from the auxiliary regression of the independent variable x_k on the other variables included in the underlying model. The VIF measures the inflation in the variances of the parameter estimates in the regression due to multicollinearity among the explanatory variables.²¹ Although the common “rule of thumb” is that a VIF that exceeds 10 is a caution that multicollinearity presents a serious problem, this rule is not definitive because the effect on the variance of the regression coefficient by itself is not sufficient to know whether multicollinearity is sufficient to undermine the quality of the regression, which in turn depends on the estimated t-statistic for the coefficient and whether the goal of the regression is to test a hypothesis (e.g., is a coefficient positive?) or to estimate the quantitative significance of a variable (as is the goal here).²² Because multicollinearity expands the confidence range of plausible values for a regression coefficient, its effect when the goal is a point estimate is more serious than when the goal is hypothesis testing. Thus, the “rule of 10” is more appropriate when, as here, the goal is estimating a regression coefficient precisely. And the values of the VIF for all of the variables that have been added by Professors Murphy and Topel are far above 10. The smallest VIF in Exhibits 3 and 4 is 37 (recharge hours in the direct sales data) and the highest VIF is 1429 (resolution in the reseller data). These values indicate that all of the additional variables cause a multicollinearity problem in the main reseller or direct sales regression.

²¹ SAS v9.3 online documentation, http://support.sas.com/documentation/cdl/en/statug/63962/HTML/default/viewer.htm#statug_reg_sect036.htm.

²² See Robert M. O’Brien, “A Caution Regarding Rules of Thumb for Variance Inflation Factors,” *Quality and Quantity* Vol. 41, No. 5 (October 2007), pp. 673-90.

Finally, even adding these variables to the regression causes estimated damages to fall, but not dramatically. The back-up Appendixes to the *Joint Report* contain regressions in which nothing was changed from the regressions in the *Noll Merits Rebuttal* other than to add the additional variables. [REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

In conclusion, nothing in the *Joint Report* supports the conclusion that additional attribute variables improve the quality of the regression. Adding these attributes to the model worsens the precision of the estimates and renders the estimates sensitive to small changes in the data and in the specification of the regression equation. The only question is whether the quality of the model would be improved by substituting some variable in the original equation with another variable. [REDACTED]

[REDACTED]

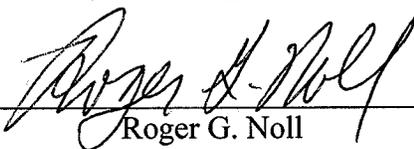
[REDACTED]

iTUNES 7.0

The *Joint Report* again asserts that the indicator variable for iTunes 4.7 should remain “on” for transactions of iPods that used iTunes 7.0. The essence of the argument

²³ The *Joint Report* states that one reason the additional variables should be added is that they increase R^2 . The additional attributes increase R^2 by small amounts: 0.0062 in the reseller regression and 0.0050 in the direct sales regression. The goal of a regression analysis is not to maximize R^2 . The problem with using a gain in R^2 , however small, as the sole criterion for evaluating whether variables should be added is that the goal of the regression is to obtain reliable, precise estimates of the coefficients on iTunes 7.0. If the additional variables create multicollinearity that undermines the precision of the estimates of the coefficients, the goal of the regression is sacrificed for a small change in R^2 .

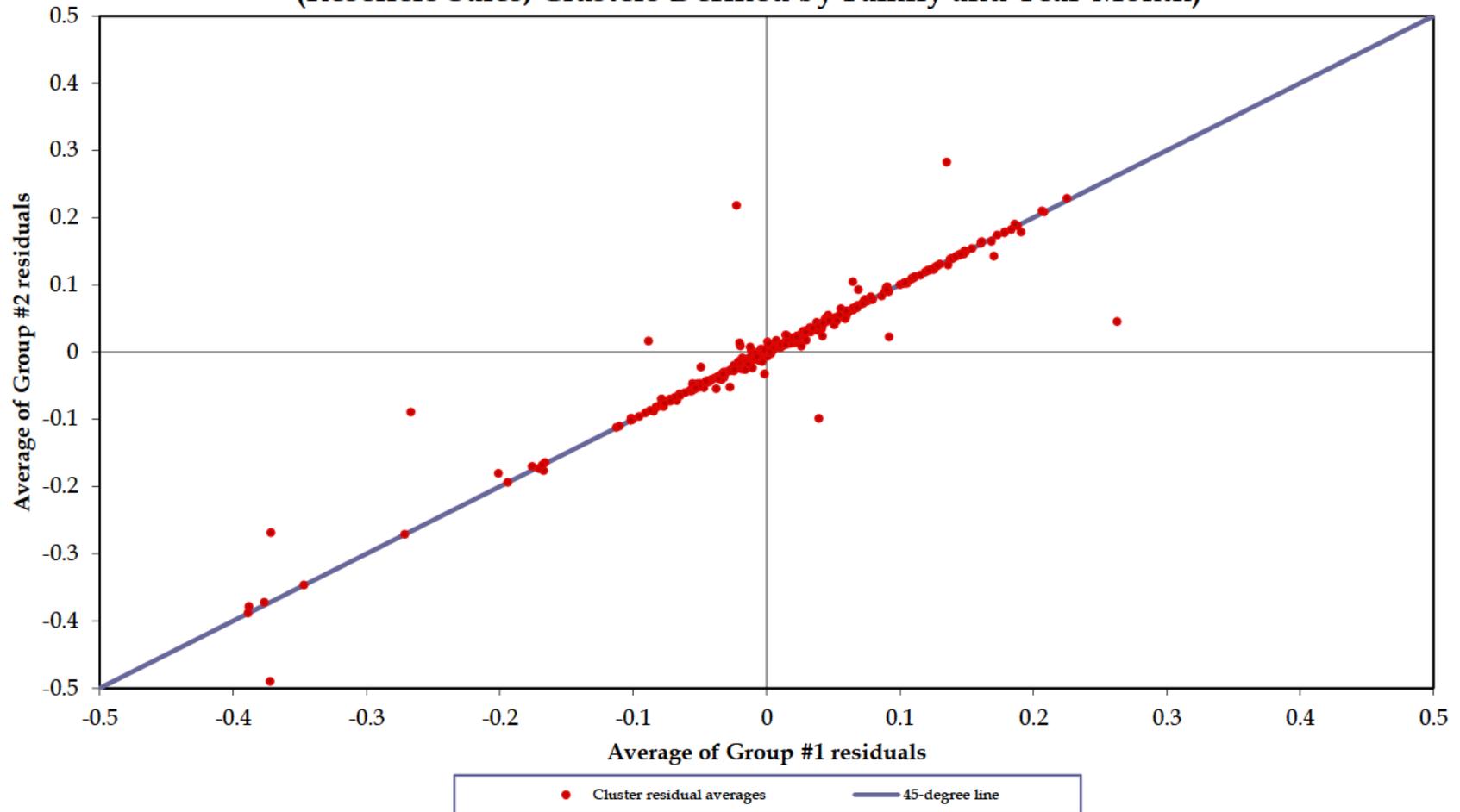
I declare that the foregoing is true to the best of my knowledge and belief.



Roger G. Noll

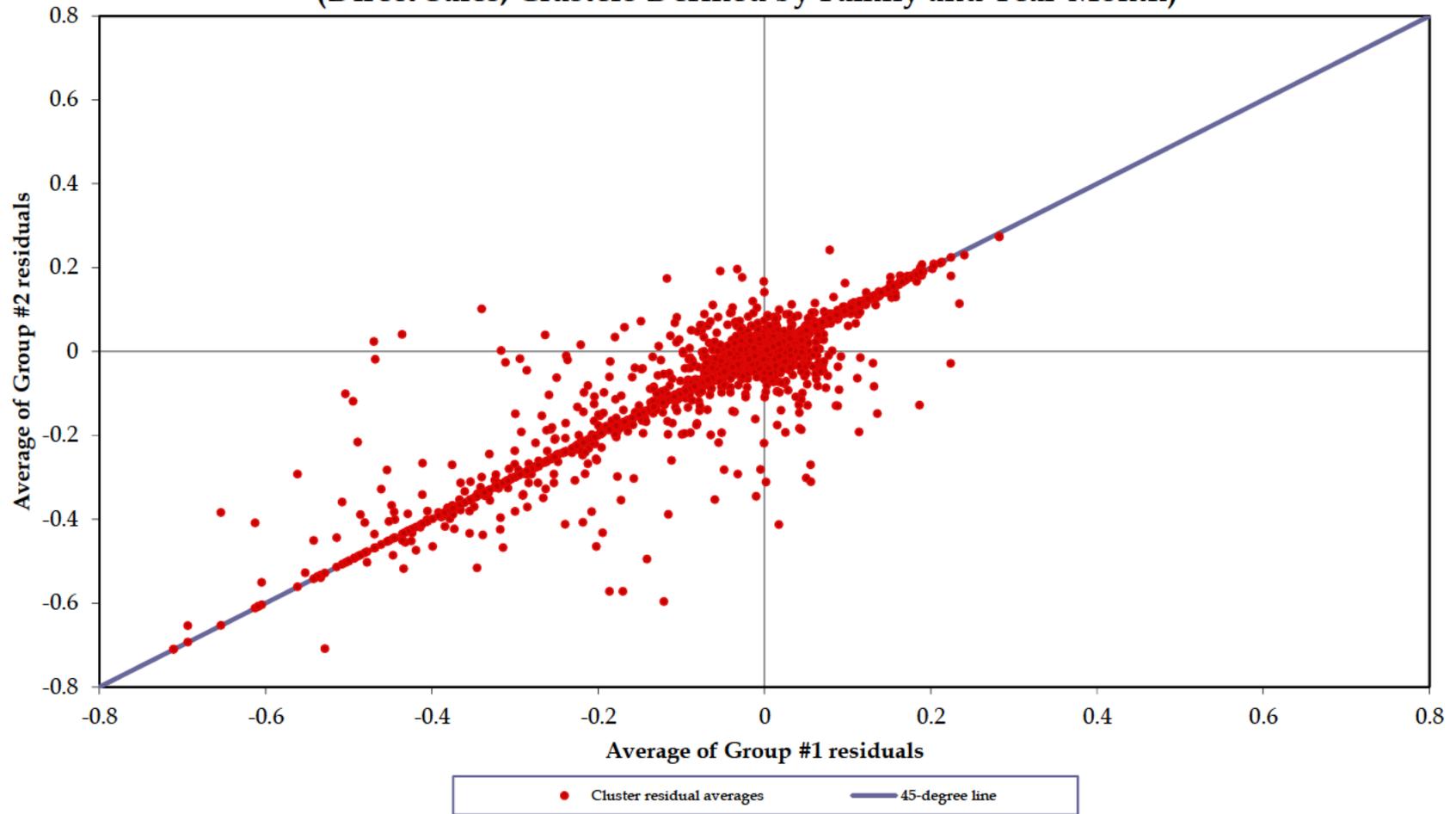
Executed at Stanford, California, on January 13, 2014.

Exhibit 1a
Average of Noll Cluster Corrected Regression Residuals
Divided Randomly in Two Groups, by Cluster
(Resellers Sales, Clusters Defined by Family and Year-Month)



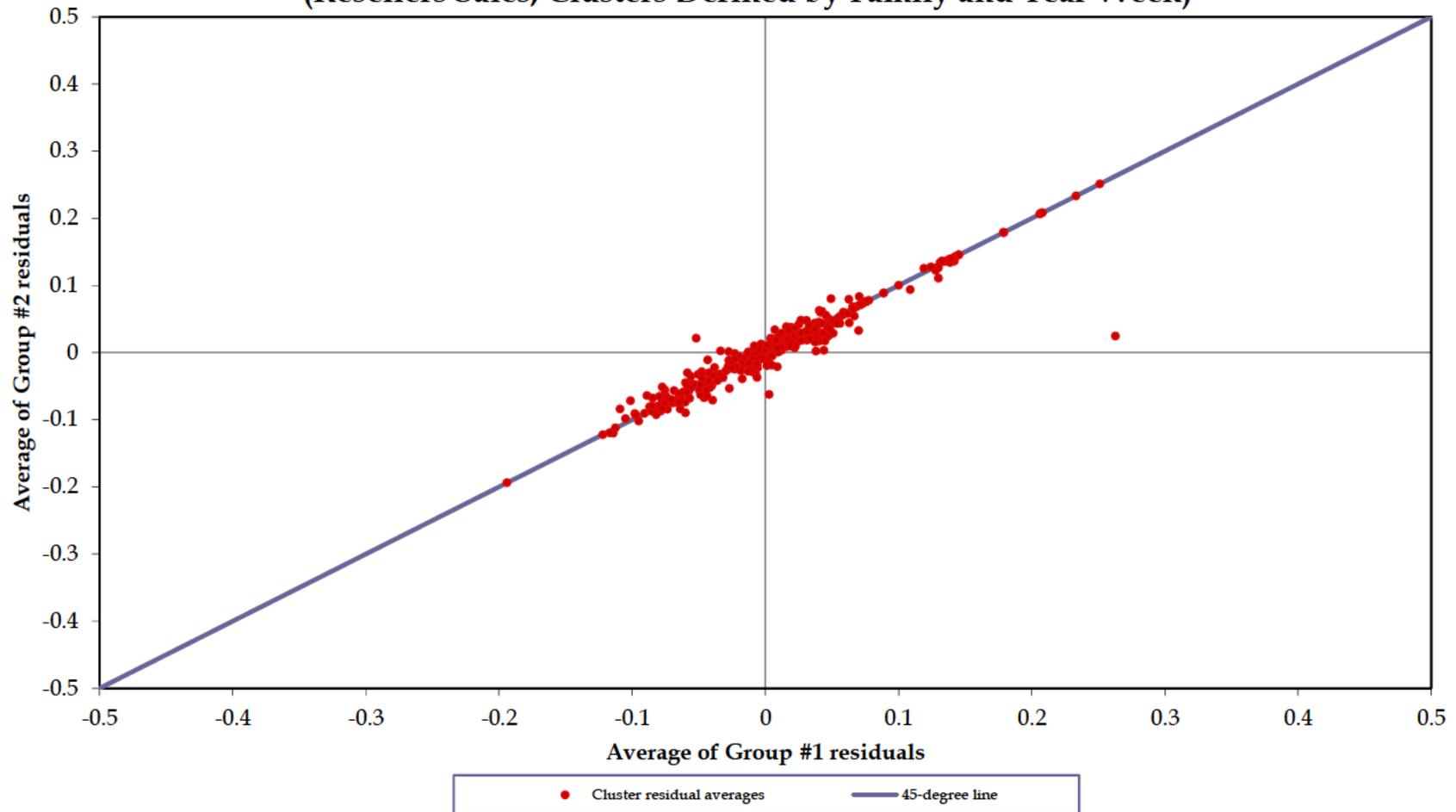
Sources: Apple iPod Sales Data

Exhibit 1b
Average of Noll Cluster Corrected Regression Residuals
Divided Randomly in Two Groups, by Cluster
(Direct Sales, Clusters Defined by Family and Year-Month)



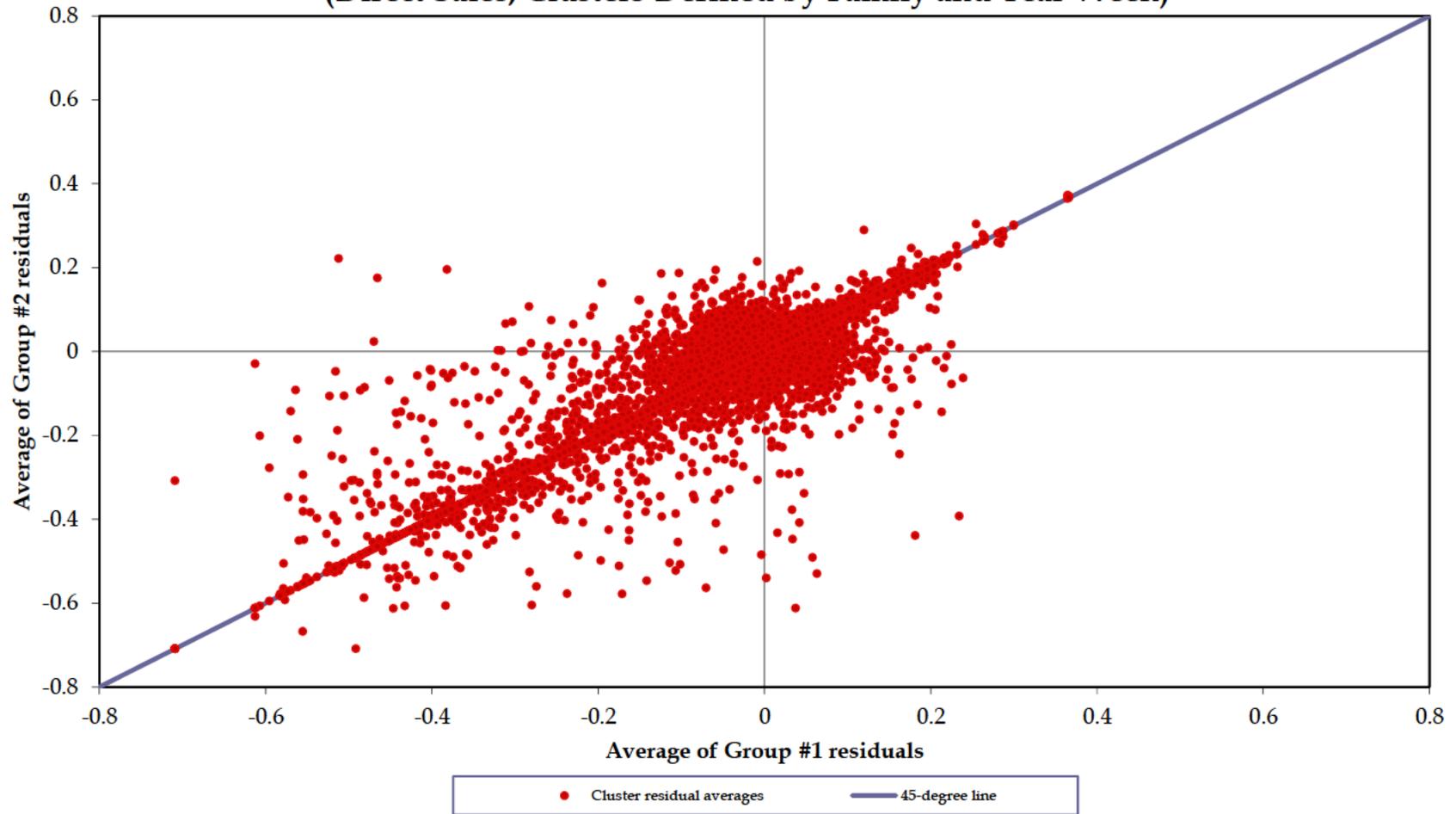
Sources: Apple iPod Sales Data

Exhibit 2a
Average of Noll Cluster Corrected Regression Residuals
Divided Randomly in Two Groups, by Cluster
(Resellers Sales, Clusters Defined by Family and Year-Week)

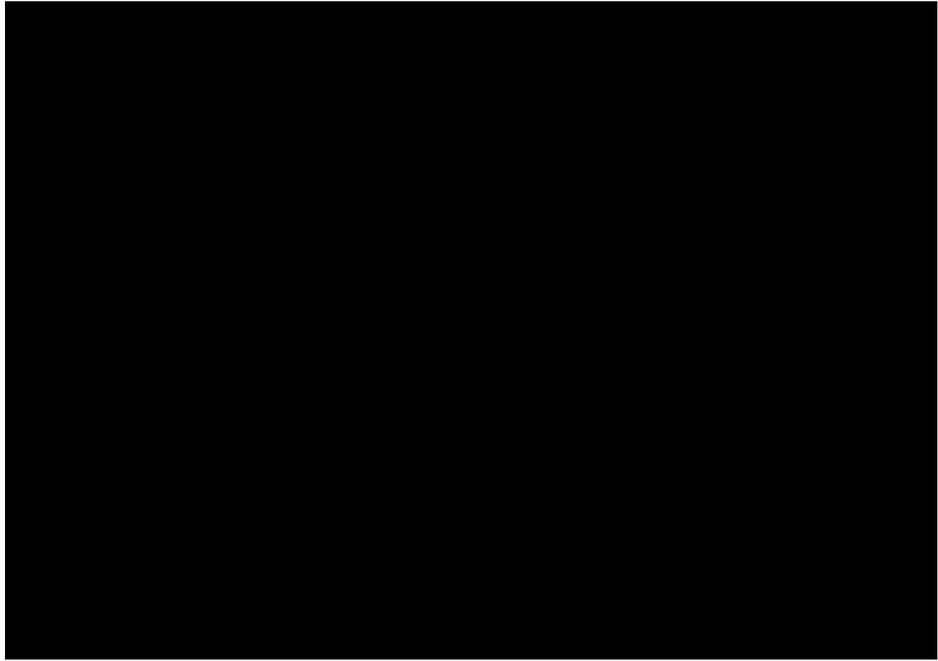


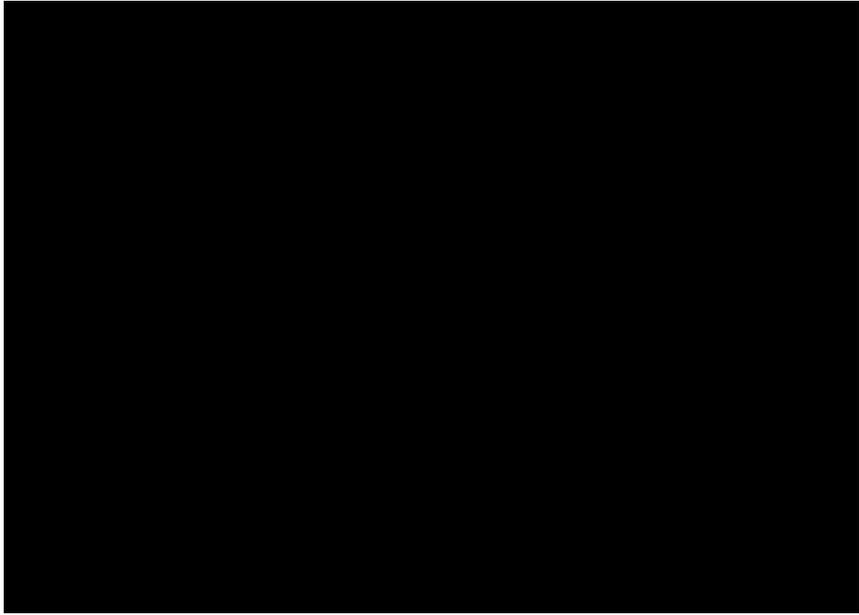
Sources: Apple iPod Sales Data

Exhibit 2b
Average of Noll Cluster Corrected Regression Residuals
Divided Randomly in Two Groups, by Cluster
(Direct Sales, Clusters Defined by Family and Year-Week)



Sources: Apple iPod Sales Data





APPLE'S (PROPOSED) REDACTIONS

EXHIBIT 54
[Filed Under Seal]

**UNITED STATES DISTRICT COURT
NORTHERN DISTRICT OF CALIFORNIA
OAKLAND DIVISION**

APPLE IPOD ITUNES
ANTITRUST LITIGATION

Lead Case No. C-05-00037-YGR

**DECLARATION OF JEFFREY M. WOOLDRIDGE IN SUPPORT OF PLAINTIFF'S
DAUBERT MOTION TO EXCLUDE CERTAIN OPINION TESTIMONY OF
ROBERT H. TOPEL AND KEVIN M. MURPHY**

1. Introduction

My name is Jeffrey M. Wooldridge. I am a University Distinguished Professor of Economics at Michigan State University (MSU), where I have taught since 1991. My first academic appointment was as an assistant professor in the economics department at the Massachusetts Institute of Technology, where I taught from 1986 to 1991.

2. Qualifications

I received bachelor's degrees in computer science and economics from the University of California, Berkeley, in 1982, and I received my doctorate in economics from the University of California, San Diego, in 1986. I am trained as an econometrician and have taught and done research on econometric methods for almost 30 years. One of my areas of expertise is problems associated with nonrandom sampling, including missing data, stratified sampling, and cluster sampling. I have written several articles about these subjects, and have given many lectures and short courses on approaches to handling nonrandom samples. I have written two popular textbooks in econometrics, an introductory book and a graduate-level text, *Econometric Analysis of Cross Section and Panel Data Methods* (2010, MIT Press, 2e). I use my MIT Press book for a

year-long course in microeconomic methods for second-year Ph.D. students, and I have based several short summer school courses on the contents of the book.

I am a Fellow of the *Econometric Society* and of the *Journal of Econometrics*. I have served on several editorial boards, including as editor of the *Journal of Business and Economic Statistics* from 1998 to 2000, as co-editor of *Econometric Theory* from 2003 to 2005, and as econometrics co-editor of *Economics Letters* from 1995 to 1998.

I have served as an econometrics consultant several times, including work for Charles Rivers Associates when I taught at MIT, Arthur Andersen, Deloitte Consulting, and, currently, for Industrial Economics, Inc, on a damage assessment project for the National Oceanic and Atmospheric Administration.

Other evidence of my qualifications as an expert in econometrics generally and on sampling issues specifically is given in my curriculum vita, which is included as Appendix A.

2. Assignment

I have been asked by the attorneys for the plaintiffs in this litigation to evaluate and reconcile differing claims about the proper calculation of standard errors in separate expert reports written by three economists, Roger G. Noll (for the plaintiffs), Kevin M. Murphy (for the defendant), and Robert H. Topel (for the defendant). In separate reports, Professors Murphy and Topel criticize the statistical inference in Professor Noll's hedonic regression analysis for not properly accounting for cluster correlation when computing standard errors for the regression coefficients – and, in particular, the standard errors for the coefficients used to estimate damages. In what follows I restrict my comments to issues associated with computing proper standard errors and do not discuss model specification. In the remainder of this declaration I describe the

clustering problem somewhat generally and determine whether and how the standard errors should be adjusted for cluster correlation in Professor Noll's regressions.

3. When is a Sample a Cluster Sample?

The simplest example of a cluster sample is when individual units are grouped, a priori, into clusters, and those clusters are sampled from a population of clusters. After the clusters have been chosen, sampling within the clusters may occur to obtain a subset of units, but the substantive problem for computing standard errors is created when the clusters are originally chosen. An example is when elementary schools in a state are sampled from the population of all elementary schools in the state. After the schools have been drawn, data are collected for the individual students – say, test scores and class sizes. If we wish to study the effects of class size on test scores then we need to address the fact that student outcomes within a school are likely to be influenced by common factors determined at the school level, such as (unmeasured) teacher or principal quality. There are a couple of appropriate responses in such settings. One is to include school “fixed effects” in the regression as a way of eliminating the cluster correlation (and also allowing the policy variable, class size, to be systematically different across schools). Or, one may compute standard errors that allow for correlation in the errors within a school. As I argue in Wooldridge (2003), in some cases one may want to try both solutions at the same time.

A common misunderstanding with cluster sampling is that a clustering problem arises if individual units that have been randomly sampled from the population are identified, ex post, as belonging to certain groups, which are then turned into clusters. For example, suppose a random sample of fourth-grade students is taken from the state of Michigan, and test scores and family background variables are collected. A school identifier for each student is also included in the data set. It would not be uncommon to sort the resulting data set so that students from the same

school are in adjacent rows in the data set. Such a data set, which was obtained via random sampling, is indistinguishable *in appearance* from a data set that was obtained by first sampling schools and then obtaining a sample of students within each sampled school. But the resemblance is superficial: When applying statistical methods, the latter requires the use of methods for cluster samples while the former does not.

A simple logical exercise demonstrates that ex post grouping of a randomly drawn sample cannot cause a clustering problem when it comes to statistical inference. After all, each randomly drawn student is also associated with a school district. If we include a school district identifier should we then treat the district as the cluster? In Michigan, groups of school districts form what are known as intermediate school districts (ISDs). Is the ISD now the appropriate level of clustering? We can keep going. Each ISD is either in the lower or upper peninsula of Michigan. Does this mean we only have two independent clusters? Taking the argument to its extreme, each student lives in the state of Michigan. Is it appropriate to think we have only a single cluster, in which case no statistical inference is possible? The final perspective is clearly preposterous, but by getting to it we see that viewing the data as a cluster sample at any level of aggregation is incorrect. If we started with a random sample then we can and should analyze the data using basic tools of statistics and econometrics based on random sampling. How we might choose to group the students ex post is irrelevant provided the variables we use in our analysis are collected as part of the random sampling scheme.

I will show in the next section that the clustering exercise undertaken by Professors Murphy and Topel fits into the framework of ex post clustering, and is therefore an inappropriate and unreliable application of clustering.

It is important to know that computing so-called “cluster-robust” standard errors is not harmless when the data have come from a random sample. (The same comment holds when the sample is the population, a point that follows from the discussion in Section 5.) Clustering can produce standard errors that are vastly inflated compared with the true precision of the estimates. In other words, estimates that are properly deemed to be statistically significant when the correct standard errors are used can be statistically insignificant when “cluster-robust” standard errors are used. Empirical researchers sometimes fall into the trap of thinking conservative inference is somehow preferred, but that is incorrect when appropriate methods of inference are available that are not conservative. If we are interested in estimating the effect of an intervention we want our confidence intervals to be as reliable as possible.

A separate problem with clustering is that, even when it is legitimate – so that the data have actually been collected by sampling clusters – we need enough clusters that are relatively small in order to justify the large-sample approximations. Hansen (2007) shows that when applied to true cluster samples one should have a reasonably large number of clusters without very large cluster sizes. See also the discussion in Donald and Lang (2007) and Wooldridge (2003). Hansen’s simulations show that clustered standard errors perform reasonably well with 50 clusters and 20 observations per cluster. But clustered standard errors are not justified with, say, 10 clusters and 200 observations per cluster. The higher is the ratio of observations per cluster to number of clusters, the more poorly clustered standard errors behave. Generally, it is difficult to know how well clustering approximates the true sampling error when the number of clusters is small and cluster sizes are large. The resulting “cluster-robust” standard errors can be very misleading as estimates of statistical precision. As I discuss in Section 4, Murphy and Topel

use clustering in a setting where the cluster sizes are much larger than the number of clusters. This is a second reason why their analysis is invalid.

There is a final, important point that needs to be emphasized before turning specifically to Professor Noll's analysis and the critiques by Professors Murphy and Topel. Namely, it is inappropriate to use the amount of variation in either the explanatory variables or the response variable across subgroups of the population as a guide for whether a data set constitutes a cluster sample. Clustering is a property of how the data are collected and has nothing to do with how much variation there is in the underlying population variable or variables. For example, suppose we are interested in testing whether a chain of fast-food restaurants practices price discrimination across two different kinds of neighborhoods – say “poor” and “not poor.” We randomly sample transactions at fast food restaurants and obtain a sample of prices of purchased items. When we sample a transaction, we observe the item bought (say, a medium soda), its price, and the kind of neighborhood (poor or not poor). Particularly if the transactions data are collected over a narrow time interval the price variation for a particular item in a particular geographic region may be small. In fact, many of the transactions would have identical prices for identical menu items – for example, small, medium, and large sodas. This does not mean that those three groups of sodas should be treated as three clusters. In fact, this would be a bad idea for the two reasons discussed above: (i) The ex post clustering of the data creates the illusion of a cluster sampling problem where none exists, seriously understating the amount of independent information we have on prices. (ii) The standard errors obtained using three clusters, probably with several hundred or thousand observations within each cluster, have no statistical justification and are for all practical purposes worthless. On the other hand, computing the average prices for each item and obtaining

standard errors under random sampling is appropriate, and standard comparison-of-means tests across poor and non-poor neighborhoods is entirely appropriate.

In this example, it would also be inappropriate to treat “poor” and “not poor” as two clusters, in which case no statistical inference concerning the difference in means would be possible because we could not even compute a standard error. [See, for example, Wooldridge (2003).] It is also inappropriate to use, say, census blocks as clusters. If the transactions have been randomly sampled from the population of all transactions then the data should be analyzed using standard statistical methods for random sampling.

4. Clustering in Professor Noll’s Hedonic Regressions

I now turn to an evaluation of the claims made by Professors Noll, Murphy, and Topel concerning the proper computation of standard errors using the transactions data for Apple iPods. In determining whether clustering is needed, it is important to understand a couple of features of the data. First, as explained by Professor Noll (rebuttal, 11/25/13), the data on transactions – apart from dropping some records with missing data or outliers in prices – effectively represents the entire population of transactions. Under a scenario that I describe in Section 5 – which views the prices as counterfactual outcomes under different “treatment” regimes (before Harmony was blocked and after it was blocked) – the standard errors computed as if the sample is random are at least conservative. Therefore, if one is satisfied with conservative inference, one need not worry about corrections that are sometimes used when the sample and population coincide.

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED]

[REDACTED] Based on my understanding of the econometrics used by Professor Noll in his rebuttal report, Professor Murphy's assertion is no longer relevant. In the analysis that forms the basis for his rebuttal report, Professor Noll did not expand each transaction into an observation for each iPod unit sold. Professor Noll *does* use quantity weights that account for the number of units in each transaction and, strictly speaking, these are the optimal weights for weighted least squares only when the unit-specific equations have independent errors. However, as I have emphasized in my introductory textbook (Wooldridge, 2013, pages 290-292), the weighted least squares standard errors can be made robust to allow for the use of non-optimal weights. The same point is discussed, in the context of sampling, in Solon, Haider, and Wooldridge (forthcoming). Professor Noll properly uses the robust standard errors. But the more important point is that Professor Noll properly uses each transaction as the unit of observation. There is no clustering problem introduced in Professor Noll's rebuttal report by expanding a transaction into several hundred or thousand observations on individual iPod units.

If one properly views a transaction as a unit of observation, as is done by Professor Noll, the data need not be treated as a cluster sample. In particular, the clustering procedure suggested by Professors Murphy and Topel, which is to cluster the data at the product family/quarter level, is inappropriate. With each shipment there is a new draw of characteristics of the units shipped, quantity, and average price, and it is appropriate to treat these as independent pieces of

information. By contrast, Professors Murphy and Topel make the mistake described in Section 3. Namely, they use an ex post clustering based on characteristics of the shipments – product family and time period. In his report, Murphy writes, “There are standard techniques that allow for clustering in the calculation of regression standard errors. If it were the case that clustering is unimportant, as assumed by Professor Noll, he could have employed these techniques to demonstrate that accounting for clusters does not affect his results” (page 51). Professor Murphy makes the mistake of assuming that clustering in the context of Professor Noll’s analysis at the product family/quarter level is statistically valid. For the two reasons I explained in Section 3, clustering is not valid, and likely to produce inference that is much too conservative: (i) The clustering of the data by product family/quarter is done ex post, artificially creating cluster correlation and unnecessarily producing conservative sampling variances. (ii) The number of observations per cluster swamps the number of clusters, rendering the cluster standard errors useless, even if we accepted the idea that clustering is needed in the first place (which I do not).

It may help to cover a simple case to further see the key difference between what is the correct standard error calculation used by Professor Noll and the incorrect calculation by Professors Murphy and Topel. Suppose there is only one iPod model with a fixed set of characteristics. We obtain transaction records for this model both before and after Harmony was blocked. For each transaction we obtain a price per iPod unit sold, and then compute the average price within the two groups. A valid standard error and t statistic is obtained by treating the transactions as independent draws – the approach used by Professor Noll. In this case, if we treat the product class as a cluster, as suggested by Murphy and Topel, we cannot even compute a standard error: the observations within the control and treatment groups are allowed to be arbitrarily correlated. Wooldridge (2003) discusses essentially this same example, and points out

that, if one follows the Murphy and Topel view, the staple of introductory statistics and basic policy analysis with random interventions, a simple comparison of means, cannot be carried out.

With more product classes and multiple time periods then, technically, one can compute clustered standard errors at the product family/quarter level – as is done in the *Murphy Report* and the *Topel Report*. But it should not be done because it produces very unreliable standard errors.

5. Inference when the Sample is the Population

Professor Noll comments in his rebuttal (page 10) that he is using the entire population of transactions, and therefore there can be no cluster sampling problem because there is no sampling. I agree with this assessment. As discussed by Professor Noll, his analysis of the transactions data is essentially an event study, or an intervention analysis. Thus, it is important to ask: At what level is the intervention? In my view, it is at the transaction level, and that is the approach taken by Professor Noll.

If we observe the entire population of shipments, how can one meaningfully introduce sampling uncertainty into the estimates? After all, if we can compute a price for every transaction in the population, we can compute the differences in average prices among various product family/time period groups without error.

One possibility, which fits well with intervention analysis, is to view the prices we observe as only one possible set of prices from a set of counterfactual prices. Consider a simple example, where there is only a single product (a particular iPod with a given set of features) and a single intervention (Harmony is blocked). Then we can view each shipment i in the population as having two potential prices, $p_i(0)$ and $p_i(1)$. The first of these is the price in the regime where Harmony is not blocked, and the second is in the regime where Harmony is blocked. The

goal is to estimate the so-called average treatment effect – see, for example, Imbens and Wooldridge (2009) – here defined as

$$\tau = N^{-1} \sum_{i=1}^N [p_i(1) - p_i(0)], \quad (1)$$

where N is the size of the population. The counterfactual nature of the thought experiment is crucial, as we observe only one of $p_i(0)$ and $p_i(1)$. Which price we observe depends on the intervention status for transaction i , which we denote using a binary (dummy) variable X_i . This variable is equal to zero for transactions observed when Harmony is not blocked and equal to one when Harmony is blocked. The observed price is then a random variable, and can be written as

$$P_i = (1 - X_i)p_i(0) + X_i p_i(1) \quad (2)$$

P_i is random because X_i is random.

Assume that X_i is assigned independent of the counterfactual prices – this is called the “unconfoundedness” assumption in the treatment effects literature (see Imbens and Wooldridge, 2009). The standard estimator of τ is the difference in the sample averages between the “treated” and “control” groups, which we denote

$$\hat{\tau} = \bar{P}_1 - \bar{P}_0. \quad (3)$$

This is an unbiased estimator of τ when the unconfoundedness assumption holds. For the purposes of statistical inference, it can be shown that the variance of the estimator, conditional on the number of treated units, N_1 , is

$$\text{Var}(\hat{\tau} | N_1) = \frac{\sigma_1^2}{N_1} + \frac{\sigma_0^2}{N_0} - \frac{\sigma_{0,1}^2}{N}, \quad (4)$$

where $N_0 = N - N_1$ is the number of control units, $\sigma_1^2 = (N - 1)^{-1} \sum_{i=1}^N [p_i(1) - \mu_1]^2$ is the population variance of the $p_i(1)$, σ_0^2 is the population variance of the $p_i(0)$, and $\sigma_{0,1}^2$ is the population variance of the treatment effects, $p_i(1) - p_i(0)$. The first two terms in equation (4) comprise the usual expression, which can be found in introductory texts on mathematical

statistics, for the variance of the difference in means when obtaining random samples from a large population. The last term is a correction that results from having access to the entire population. When the treatment effect is constant, so that $p_i(1) - p_i(0) = \tau$ for all i , the last term is zero, and the usual variance formula obtained under random sampling holds when we observe the entire population. In general, the usual formula is actually conservative. An important implication is that the reported standard errors actually overstate the sampling variation in $\hat{\tau}$, resulting in conservative inference: If one finds statistical significance using the usual standard errors then the estimates would be significant if one accounted for the final term in (4).

The analysis for multiple regression is more complicated but the findings are similar: using the usual heteroskedasticity-robust variance matrix estimator is at least conservative. Professor Noll uses the heteroskedasticity-robust variance matrix estimator and so his inference is appropriate.

The previous discussion also has relevance for the cluster sampling issue. Because, hypothetically, each transaction could have been in multiple states of the world – different time periods, different models shipped, before and after Harmony was blocked – it makes sense to view the intervention for each transaction as an independent assignment. Therefore, there can be no cluster sampling issue in the setting analyzed by Professor Noll. On the other hand, if we sampled an entire population of clusters – such as all elementary schools in a particular state – in order to evaluate a school-level intervention, then we should treat each school as its own cluster of individual students. The conclusion would be that the usual cluster-sample inference obtained for sampling clusters from a large population results in conservative inference. But this is a different setting than the one studied by Professor Noll.

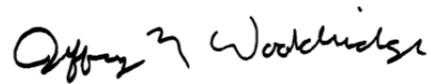
6. Summary

(i) Clustering is inappropriate where, as here, the regressions use the entire population of transactions. There can be no cluster sampling problem because there is no sampling.

(ii) Professor Noll's use of heteroskedasticity-robust standard errors is appropriate. By contrast, Professors Murphy and Topel, who suggest clustering at the family product/quarter level, are guilty of ex post clustering. Their standard error calculations are much too imprecise.

(iii) Computing "cluster-robust" standard errors where, as here, clustering is not appropriate, is not harmless. Clustering can produce standard errors that are vastly inflated compared with the true precision of the estimates.

I declare that the foregoing is true to the best of my knowledge and belief.



Jeffrey M. Wooldridge

Executed at Mason, Michigan, December 20, 2013

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- Solon, G., S.J. Haider, and J.M. Wooldridge (forthcoming), "What Are We Weighting For?" *Journal of Human Resources*.
- Wooldridge, J.M. (2003), "Cluster-Sample Methods in Applied Econometrics," *American Economic Review* 93, 133-138.
- Wooldridge, J.M. (2010), *Econometric Analysis of Cross Section and Panel Data*, second edition. Cambridge, MA: MIT Press.

Appendix A

CURRICULUM VITAE

JEFFREY M. WOOLDRIDGE

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1. ACADEMIC POSITIONS HELD

University Distinguished Professor of Economics, Michigan State University: July 1, 2001 to present.

Co-Director, Economics of Education Specialization, Michigan State University: July 2009 to present.

Professor of Economics, Michigan State University: July 1, 1993 to June 30, 2001.

Associate Professor of Economics, Michigan State University: September 1, 1991 to June 30, 1993.

Assistant Professor of Economics, Massachusetts Institute of Technology: June 1, 1986 to June 30, 1991.

2. ACADEMIC BACKGROUND

Ph.D., Economics, University of California, San Diego, 1986

B.A., Computer Science, B.A., Economics, University of California, Berkeley, 1982 (With High Distinction in General Scholarship)

3. TEACHING

Graduate: Linear Models, Nonlinear Econometrics, Cross Section and Panel Data Econometrics, Applied Econometrics, Mathematical Statistics, Mathematics for Economics

Undergraduate: Econometrics, Applied Econometrics, Statistics

4. SOCIETY MEMBERSHIPS

American Economic Association
American Statistical Association
Econometric Society
Midwest Economics Association

5. EDITORIAL BOARDS

Co-Editor, *Journal of Econometric Methods*, 2010 to present.

Editorial Board, *Journal of Economic Literature*, 2004 to 2010.

Co-Editor, *Econometric Theory*, 2003 to 2005.

Advisory Editor, the *Palgrave Handbook of Econometrics*, 2004-2005.

Editor, *Journal of Business and Economic Statistics*, 1998 to 2000.

Co-Editor, *Economics Letters*, 1995 to 1998.

Associate Editor, *Stata Journal*, 2002 to present.

Associate Editor, *Journal of Business and Economic Statistics*, 1995 to 1997.

Associate Editor, *Journal of Econometrics*, 1995 to 1997; 2001 to 2005.

Associate Editor, *Review of Economics and Statistics*, 1993 to 1997.

6. AWARDS AND HONORS

President, Midwest Economics Association, 2010-2011.

Fellow, Institute for the Study of Labor (IZA), Bonn, Germany, elected 2009.

President-elect, Midwest Economics Association, 2009-2010.

First Vice President, Midwest Economics Association, 2005-2006.

Fellow of the Econometric Society, elected 2002.

Plura Scripsit Award, *Econometric Theory*, elected 2001.

Benjamin Meaker Visiting Professorship, University of Bristol, England, July 2000.

Richard Stone Prize for “Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates” (with Leslie E. Papke), *Journal of Applied Econometrics*, 1998. (Best paper in two volumes.)

Multa Scripsit Award, *Econometric Theory*, elected 1997.

Journal of Econometrics Fellow, elected November 1995.

Alfred P. Sloan Research Fellow, 1991-1994.

Teacher of the Year Award, Graduate Economics Association, MIT, 1991-1992.

Teacher of the Year Award, Graduate Economics Association, MIT, 1990-1991.

Teacher of the Year Award, Graduate Economics Association, MIT, 1988-1989.

Alfred P. Sloan Doctoral Dissertation Fellowship, 1985-1986.

Sea Grant Predoctoral Traineeship, 1983.

Regents Fellowship, University of California, 1982-1984.

7. PROFESSIONAL

Econometric Society Fellows Nominating Committee, 2006.

Scientific Committee, International Panel Data Conference, 2006, 2009, 2011, 2012.

Advisory Panel, National Science Foundation, Mathematical Social and Behavioral Sciences Competition, Arlington, VA, May 2005.

Occasional Consultant, Industrial Economics, Inc.

Occasional Consultant, Stratus Consulting

Occasional Consultant, Deloitte Consulting

Occasional Consultant, Washington State Institute for Public Policy

Occasional Consultant, Arthur Andersen, Chicago, Illinois, 1995 to 2001

Occasional Consultant, Charles River Associates, Boston, Massachusetts, 1987 to 1996

8. PRESENTATIONS AT MEETINGS

Invited Speaker, Mainz Econometrics Workshop, “Control Function Methods in Applied Econometrics,” Mainz, Germany, August 2013.

Invited Speaker, Sydney Econometric Theory Workshop: “Quasi-Maximum Likelihood Estimation and Testing for Nonlinear Models with Endogenous Explanatory Variables,” Sydney, Australia, July 2012.

A.W. Phillips Lecture, Econometric Society Australasian Meeting, “Nonlinear Panel Data Models with Heterogeneity and Endogeneity,” Melbourne, Australia, July 2012.

Invited Speaker, Stata Conference: “Fractional Response Models with Endogenous Explanatory Variables and Heterogeneity,” Chicago, IL, July 2011.

Invited Speaker, Causality, Prediction, and Specification Analysis: Recent Advances and Future Directions – A Conference in Honore of Halbert L. White, Jr.: “Quasi-Maximum Likelihood Estimation and Testing for Nonlinear Models with Endogenous Explanatory Variables,” La Jolla, CA, May 2011.

Presidential Address, Midwest Economics Association: “Thoughts on Heterogeneity in Econometric Models,” St. Louis, MO, March 2011.

Keynote Speaker, Health Econometrics Workshop: “Correlated Random Effects Models with Unbalanced Panels,” Ann Arbor, MI, October 2010.

Invited Speaker, 15th Conference on Panel Data: “Nonlinear Correlated Random Effects Models with Unbalanced Panels,” Bonn, Germany, July 2009.

Invited Speaker, Canadian Econometrics Study Group: “Nonlinear Dynamic Panel Data Models with Unobserved Effects,” Montréal, Quebec, September 2008.

“Nonparametric and Semiparametric Estimation of Partial Effects for Nonlinear Panel Data Models,” Workshop on Nonparametric/Semiparametric Econometric Methods, Carleton University, Ottawa, Ontario, September 2008.

Invited Speaker, Summer North American Stata Users Group: “Inference for Partial Effects in Nonlinear Panel Data Models using Stata,” Chicago, IL, July 2008.

Featured Speaker, National Value-Added Modeling Conference: “Some Econometric Considerations for Value-Added Modeling,” Madison WI, April 2008.

“Estimating Average Treatment Effects with Continuous and Discrete Covariates: The Case of Swan-Ganz Catheterization,” Winter Meetings of the American Economic Association, New Orleans, January 2008.

Panel Member, “How to Mentor Junior Economists,” Winter Meetings of the American Economic Association, New Orleans, January 2008.

“Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates” (with L.E. Papke), Conference on *The Use of Econometrics in Informing Public Policy Makers*, Rice University, April 2006.

Panel Member, Midwest Economics Association, Chicago, March 2006: “Teaching Econometrics.”

Discussant, Midwest Economics Association, Chicago, March 2006: “Applied Time Series.”

Discussant, Winter Meetings of the Econometric Society, Philadelphia, January 2005: “Causal Inference and Matching.”

“Inverse Probability Weighted M-Estimators for General Missing Data Problems,” Texas Camp Econometrics, Fort Worth, TX, February 2004.

“On the Robustness of Fixed Effects and Related Estimators in Correlated Random Coefficient Panel Data Models,” Midwest Econometrics Group, Columbia, MO, October 2003.

“Cluster-Sample Methods in Applied Econometrics,” Winter Meetings of the American Economic Association,” Washington, DC, January 2003.

Discussant, Winter Meetings of the Econometric Society, Washington, DC, January 2003: “Difference-in-Differences and Panel Data Estimation.”

“Inverse Probability Weighted M-Estimators for Sample Selection, Attrition, and Stratification,” CeMMAP Microeconometrics Workshop, London, February 2002.

“Inverse Probability Weighted M-Estimators for Sample Selection, Attrition, and Stratification,” Midwest Econometrics Group, Kansas City, October 2001.

“Unobserved Heterogeneity and Estimation of Average Partial Effects,” National Science Foundation Symposium on *Identification and Inference for Econometric Models*, Berkeley, August 2001.

“Applications of Generalized Method of Moments Estimation,” Winter Meetings of the American Economic Association,” New Orleans, January 2001.

Discussant, Winter Meetings of the Econometric Society, New Orleans, January 2001: “Recent Advances in Nonlinear Time Series.”

Invited Speaker, ESRC Econometric Study Group Conference, Bristol, England, July 2000: “The Initial Conditions Problem in Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity.”

Discussant, Joint Statistical Meetings, Indianapolis, August 2000: *Journal of Business and Economic Statistics* Invited Session.

Plenary Speaker, Research Triangle Econometrics Conference, December 1998: “Estimating Average Partial Effects Under Conditional Moment Independence Assumptions.”

Discussant, Winter Meetings of the Econometric Society, Chicago, January 1998: “Panel Time Series” and “New Developments in Technical Econometrics.”

“Selection Corrections with a Censored Selection Variable,” Canadian Econometrics Study Group, Windsor, September 1994.

Discussant, Joint Statistical Meetings, Toronto, August 1994: “Analysis of Data on Durations and Counts.”

Discussant, Summer Meetings of the Econometric Society, Quebec City, June 1994: “Panel Data Methods” and “Testing Using Nonparametric Methods.”

Discussant, Winter Meetings of the Econometric Society, Anaheim, January 1993: “Simulation and Semiparametric Methods” and “Estimation and Testing in Systems of Equations.”

“Multiplicative Panel Data Models without the Strict Exogeneity Assumption,” Midwest Econometrics Group, South Bend, IN, September 1991.

Discussant, Winter Meetings of the Econometric Society, Washington, DC, December 1990: “Semiparametric Methods,” “Unit Roots and Cointegration: Methodology,” and “Specification Testing.”

“Some Results on Specification Testing Against Nonparametric Alternatives,” Summer Meetings of the Econometric Society, Ann Arbor, MI, July 1989.

Discussant, Summer Meetings of the Econometric Society, Ann Arbor, MI, July 1989: “Specification Tests.”

“An Encompassing Approach to Conditional Mean Tests with Applications to Testing Nonnested Hypotheses,” Winter Meetings of the Econometric Society, New York, December 1988.

Discussant, Summer Meetings of the Econometric Society, Minneapolis, July 1988: “Time Series I.”

“A Capital Asset Pricing Model with Time-Varying Covariances,” World Congress of the Econometric Society, Cambridge, MA, August 1985.

9. SEMINARS

“A Control Function Approach to Estimating Switching Regression Models with Endogenous Explanatory Variables and Endogenous Switching,” MSU, 2013.

“Evaluating Specification Tests in the Context of Value-Added Estimation,” Vanderbilt, 2012.

“Quasi-Maximum Likelihood Estimation and Testing for Nonlinear Models with Endogenous Explanatory Variables,” EIEF, 2011. U.C. Riverside, University College London, 2012.

“Correlated Random Effects Models with Unbalanced Panels,” MSU, 2009; Bank of Italy, 2011.

“Minimum Distance Estimation Using Pseudo Panel Data,” MSU, Michigan, 2008.

“Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates”: Harvard/MIT, British Columbia, 2007-2008.

“Inverse Probability Weighted Estimation for General Missing Data Problems”: Berkeley, Harvard/MIT, Michigan, Montreal, Notre Dame, Ohio State, Penn State, Texas, 2002-2006.

“On the Robustness of Fixed Effects and Related Estimators in Correlated Random Coefficient Panel Data Models”: Texas A&M, 2004.

“Unobserved Heterogeneity and Estimation of Average Partial Effects”: UCLA, UCSD, 2003.

“Simple Solutions to the Initial Conditions Problem for Dynamic, Nonlinear Panel Data Models with Unobserved Effects”: Michigan, 2002.

“Instrumental Variables Estimation of the Average Treatment Effect in the Correlated Random Coefficient Model”: NYU, 2000.

“Inverse Probability Weighted M-Estimators for Sample Selection, Attrition, and Stratification”: University College London, 2000.

“The Initial Conditions Problem for Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity”: Penn State, 2000.

“Estimating Average Partial Effects Under Conditional Moment Independence Assumptions”: Princeton, Northwestern, Harvard/MIT, Chicago, Bristol, 1997-2000.

“Asymptotic Properties of Weighted M-Estimators for Variable Probability Samples”: Michigan, Research Triangle Institute, 1996-1997.

“Selection Corrections with a Censored Selection Variable”: Georgia State, Texas, Texas A&M, Arizona State, Montreal, Florida, Virginia, 1994-1996.

“Selection Corrections for Panel Data Models Under Conditional Mean Independence Assumptions”: Research Triangle Institute, UCSD, Ohio State, Harvard/MIT, 1992-1993.

“Multiplicative Panel Data Models without the Strict Exogeneity Assumption”: Northwestern, Purdue, Texas A&M, Rice, Windsor, Wisconsin, 1991-1992.

“Distribution-Free Estimation of Some Nonlinear Panel Data Models”: Yale, Harvard, Michigan, Michigan State, Northeastern, 1990-1991.

“Some Alternatives to the Box-Cox Regression Model”: Boston College, Montreal, 1989.

“A Test for Functional Form Against Nonparametric Alternatives”: Harvard, Berkeley, UCSD, UCSB, Pennsylvania, Rochester, 1989.

“On the Application of Robust, Regression-Based Diagnostics to Models of Conditional Means and Conditional Variances”: Princeton, Johns Hopkins, Indiana, Illinois, Board of Governors of the Federal Reserve, Brown, 1988-1989.

“A Unified Approach to Robust, Regression-Based Specification Tests”: Brandeis, Carnegie-Mellon, Queen’s, Toronto, Johns Hopkins, Chicago Graduate School of Business, Northwestern, Cornell, UCSD, Penn State, Columbia, 1987-1988.

“Specification Testing and Quasi-Maximum Likelihood Estimation”: Harvard, Yale, Johns Hopkins, 1986-1987.

10. LECTURES AND SHORT COURSES

University of Mainz Summer School, “New Developments in Panel Data Econometrics,” Mainz, Germany, August 2013.

University of Crete Advanced Summer School in Economics and Econometrics, “Panel Data Econometrics and Treatment Effect Estimation,” Crete, Greece, July/August 2013.

IZA European Summer School in Labor Economics, “Correlated Random Effects Panel Data Models,” Buch/Ammersee, Germany May 2013.

American Accounting Association Workshop, “Linear and Nonlinear Panel Data Models,” Washington, DC, August 2012.

National Centre for Econometric Research, Queensland University of Technology, “Panel Data Econometrics,” Brisbane, Australia, July 2012.

Programme Evaluation for Policy Analysis, Institute for Fiscal Studies, “Microeconomic Methods in Policy Evaluation,” London, June 2012.

Distinguished Visitor, “Control Function Methods in Econometrics,” University of California, Riverside, May 2012.

American Economic Association, “Cross-Section Econometrics” (with Guido Imbens), Chicago, January 2012.

American Accounting Association (FARS Division), “Treatment Effect Estimation with Unconfounded Assignment,” Chicago, January 2012.

LABOUR Lectures, EIEF, “Topics in Microeconometrics,” Rome, October 2011.

CIDE Summer School in Econometrics, “Topics in Panel Data Econometrics,” Bertinoro, Italy, June 2011.

Czech National Bank, “Topics in Panel Data Econometrics,” Prague, May 2011.

Bonn Graduate School of Economics/IZA, “Treatment Effect Estimation and Selection Models,” Bonn, Germany, July 2009.

Cemmap/University College London, “New Developments in Econometrics” (with Guido Imbens), London, June 2009.

Canadian Labour Market and Skills Researcher Network/Canadian Economics Association, “A Workshop in Applied Econometrics” (with Guido Imbens), Toronto, ON, May 2009.

International Monetary Fund, “Limited Dependent Variables,” Washington, DC, April 2009.

American Economic Association, “Cross-Section Econometrics” (with Guido Imbens), San Francisco, CA, January 2009.

Federal Reserve Board, “A Course in Applied Econometrics,” Washington, DC, September-October 2008.

Michigan State University Center for Statistical Training and Consulting, “Control Function and Related Methods,” East Lansing, MI, October 2008.

Invited Speaker, Canadian Econometrics Study Group, “Nonlinear Dynamic Panel Data Models with Unobserved Effects,” Montreal, QU, September 2008.

Carleton University Workshop on Robust Nonparametric Methods, “Semiparametric and Nonparametric Estimation of Partial Effects in Nonlinear Panel Data Models,” Ottawa, ON, September 2008.

Institute for Research on Poverty, University of Wisconsin, Madison, “A Course in Applied Microeconometrics” (with Guido Imbens), August 2008.

Stata North American Users' Group, "Inference for Partial Effects in Nonlinear Panel Data Models using Stata," Chicago, IL, July 2008.

National Conference on Value-Added Modeling, "Some Econometric Considerations for Value-Added Modeling," Madison, WI, April 2008.

Michigan State University Center for Statistical Training and Consulting, "Regression and Propensity Score Methods for Treatment Effect Estimation and Policy Evaluation," East Lansing, MI, April 2008.

Michigan State University Department of Accounting, "Research Workshop on Selection Models," East Lansing, MI, April 2008.

Bureau of Economic Analysis/Federal Trade Commission, "A Course in Applied Microeconometrics" (with Guido Imbens), Washington, DC, January/February 2008.

National Bureau of Economic Research Summer Institute (with Guido Imbens), Cambridge MA: "What's New in Econometrics?" July/August 2007.

Invited Lecturer, University of Helsinki/MTT, "Econometric Methods with Censored Data," Helsinki, Finland, June 2007.

Michigan State University Center for Statistical Training and Consulting, "Propensity Score Methods for Treatment Effect Estimation and Policy Evaluation," East Lansing, MI, April 2007.

Michigan State University Center for Statistical Training and Consulting, "Binary Response Models for Longitudinal Data," East Lansing, MI, August 2006.

Invited Lecture, NIPE Summer School, University of Minho, "Topics in Program Evaluation," Minho, Portugal, June 2006.

Invited Lecturer, CIDE Summer School in Econometrics, "Topics in Panel Data Econometrics," Bertinoro, Italy, June 2005.

Mathematical Economics Forum, Wake Forest University: "Econometric Issues in Estimating Performance Effects of Spending in K-12 Schools," October 2004.

Invited Lecturer, Banco de Portugal, Lisbon: "Topics in Microeconometrics," June 2004.

Seminars on Analytical Methods, Statistics Canada, Ottawa, Ontario: "Cluster-Sample Methods in Applied Econometrics," April 2004.

XIVth Summer School of the European Economic Association, London: "Discrete Response Models," September 2003.

Methods Workshop, Lister Hill Center for Health Policy, University of Alabama, Birmingham: “Cluster-Sample Methods in Applied Econometrics,” March 2003.

Rodgers Clark Invited Lecturer, North Carolina State University: “Simple Solutions to the Initial Conditions Problem in Nonlinear, Dynamic Panel Data Models with Unobserved Effects,” April 2002.

Invited Lecturer, Western Michigan University: “Estimation and Inference for Dependent Processes” and “Selection Corrections for Cross Section and Panel Data,” February-March 1994.

Invited Lecturer, University of Pennsylvania: “Topics in Specification Testing,” January 1991.

Invited Lecturer, Universidad Complutense de Madrid: “The Econometric Treatment of Nonstationary Time Series,” November 1990.

11. BIBLIOGRAPHY

Journal Articles

“What Are We Weighting For?” (with G. Solon and S.J. Haider), forthcoming, *Journal of Human Resources*.

“Can Value-Added Measures of Teacher Performance be Trusted?” (with C.M. Guarino and M.D. Reckase), forthcoming, *Education Finance and Policy*.

“Quasi-Maximum Likelihood Estimation and Testing for Nonlinear Models with Endogenous Explanatory Variables,” forthcoming, *Journal of Econometrics*.

“Estimation of Dynamic Panel Data Models with Sample Selection” (with A. Semykina), *Journal of Applied Econometrics* 28, 47-61, January/February 2013.

“Partial Maximum Likelihood Estimation of Spatial Probit Models” (with H. Wang and E.M. Iglesias), *Journal of Econometrics* 172, 77-89, January 2013.

“A Simple Method for Estimating Unconditional Heterogeneity Distributions in Correlated Random Effects Models,” *Economics Letters* 113, 12-15, October 2011.

“Estimating Panel Data Models in the Presence of Endogeneity and Selection” (with A. Semykina), *Journal of Econometrics* 157, 375-380, August 2010.

“On Estimating Firm-Level Production Functions Using Proxy Variables to Control for Unobservables,” *Economics Letters* 104, 112-114, September 2009.

“Efficient Estimation of Average Treatment Effects with Mixed Categorical and Continuous Data” (with Q. Li and J.S. Racine), *Journal of Business and Economic Statistics* 27, 206-223, April 2009.

“Recent Developments in the Econometrics of Program Evaluation” (with G.W. Imbens), *Journal of Economic Literature* 47, 5–86, March 2009.

“Difference-in-Differences Estimation,” *Quantile* 6, 25-46, March 2009. (In Russian.)

“Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates” (with L.E. Papke), *Journal of Econometrics* 145, 121-133, July 2008.

“Estimating Average Treatment Effects with Continuous and Discrete Covariates: The Case of Swan-Ganz Catheterization” (with Q. Li and J.S. Racine), *American Economic Review* 98, 357-362, May 2008.

“Fixed Effects Instrumental Variables Estimation in Correlated Random Coefficient Panel Data Models” (with I. Murtazashvili), *Journal of Econometrics* 142, 539-552, January 2008.

“Inverse Probability Weighted M-Estimation for General Missing Data Problems,” *Journal of Econometrics* 141, 1281-1301, December 2007.

“Violating Ignorability of Treatment by Controlling for Too Many Factors,” *Econometric Theory* 21, 1026-1028, October 2005.

“Instrumental Variables Estimation with Panel Data,” *Econometric Theory* 21, 865-869, August 2005.

“Fixed Effects and Related Estimators for Correlated Random-Coefficient and Treatment Effect Panel Data Models,” *Review of Economics and Statistics* 87, 385-390, May 2005.

“A Computational Trick for Delta-Method Standard Errors” (with L.E. Papke), *Economics Letters* 86, 413-417, March 2005.

“Simple Solutions to the Initial Conditions Problem for Dynamic, Nonlinear Panel Data Models with Unobserved Heterogeneity,” *Journal of Applied Econometrics* 20, 39-54, January 2005.

“Cluster-Sample Methods in Applied Econometrics,” *American Economic Review* 93, 133-138, May 2003.

“Further Results on Instrumental Variables Estimation of Average Treatment Effects in the Correlated Random Coefficient Model,” *Economics Letters* 79, 185-191, May 2003.

“ \sqrt{n} -Consistent Estimation of a Partial Linear Model with Generated Regressors” (with Q. Li), *Econometric Theory* 18, 625-645, June 2002.

“Inverse Probability Weighted M-Estimators for Sample Selection, Attrition, and Stratification,” *Portuguese Economic Journal* 1, 117-139, June 2002.

“Applications of Generalized Method of Moments Estimation,” *Journal of Economic Perspectives* 15, 87-100, November 2001.

“Asymptotic Properties of Weighted M-Estimators for Standard Stratified Samples,” *Econometric Theory* 17, 451-470, April 2001.

“A Framework for Estimating Dynamic, Unobserved Effects Panel Data Models with Possible Feedback to Future Explanatory Variables,” *Economics Letters* 68, 245-250, September 2000.

“Asymptotic Properties of Weighted M-Estimators for Variable Probability Samples,” *Econometrica* 67, 1385-1406, November 1999.

“Efficient Estimation of Panel Data Models with Strictly Exogenous Explanatory Variables” (with K.S. Im, S.C. Ahn, and P. Schmidt), *Journal of Econometrics* 93, 177-201, November 1999.

“Distribution-Free Estimation of Some Nonlinear Panel Data Models,” *Journal of Econometrics* 90, 77-97, May 1999.

“On Two Stage Least Squares Estimation of the Average Treatment Effect in Random Coefficient Models,” *Economics Letters* 56, 129-133, October 1997.

“Multiplicative Panel Data Models without the Strict Exogeneity Assumption,” *Econometric Theory* 13, 667-678, October 1997.

“Econometric Methods for Fractional Response Variables with an Application to 401(k) Plan Participation Rates” (with L.E. Papke), *Journal of Applied Econometrics* 11, 619-632, November-December, 1996.

“Estimating Systems of Equations with Different Instruments for Different Equations,” *Journal of Econometrics* 74, 387-405, October 1996.

“Selection Corrections for Panel Data Models Under Conditional Mean Independence Assumptions,” *Journal of Econometrics* 68, 115-132, July 1995.

“A Simple Test for the Consistency of Dynamic Linear Regression in Rational Distributed Lag Models” (with K.T. McClain), *Economics Letters* 48, 235-240, June 1995.

“On the Limits of GLM for Specification Testing: A Comment on Gurnu and Trivedi,” *Econometric Theory* 10, 409-418, June 1994.

“A Simple Specification Test for the Predictive Ability of Transformation Models,” *Review of Economics and Statistics* 76, 59-65, February 1994.

“Contrastes de Especificación en Modelos Lineales con Variables Integradas” (Specification Testing in Linear Models with Integrated Variables), *Cuadernos Economicos de ICE* 55, 243-261, 1993.

“An Empirical Investigation of the Box-Cox Model and a Nonlinear Least Squares Alternative” (with E. Berndt and M. Showalter), *Econometric Reviews* 12, 65-102, March 1993.

“A Test for Functional Form Against Nonparametric Alternatives,” *Econometric Theory* 8, 452-475, December 1992.

“Some Alternatives to the Box-Cox Regression Model,” *International Economic Review* 33, 935-955, November 1992.

“Quasi-Maximum Likelihood Estimation and Inference in Dynamic Models with Time-Varying Covariances” (with T. Bollerslev), *Econometric Reviews* 11, 143-172, September 1992.

“A Note on Computing R-Squared and Adjusted R-Squared for Trending and Seasonal Data,” *Economics Letters* 36, 49-54, May 1991.

“Specification Testing and Quasi-Maximum Likelihood Estimation,” *Journal of Econometrics* 48, 29-55, April 1991.

“On the Application of Robust, Regression-Based Diagnostics to Models of Conditional Means and Conditional Variances,” *Journal of Econometrics* 47, 5-46, January 1991.

“A Note on the Lagrange Multiplier and F-statistics for Two Stage Least Squares Regressions,” *Economics Letters* 34, 151-155, November 1990.

“An Encompassing Approach to Conditional Mean Tests with Applications to Testing Nonnested Hypotheses,” *Journal of Econometrics* 45, 331-350, September 1990.

“A Unified Approach to Robust, Regression-Based Specification Tests,” *Econometric Theory* 6, 17-43, March 1990.

“A Computationally Simple Heteroskedasticity and Serial Correlation Robust Standard Error for the Linear Regression Model,” *Economics Letters* 31, 239-243, December 1989.

“Some Invariance Principles and Central Limit Theorems for Dependent Heterogeneous Processes” (with H. White), *Econometric Theory* 4, 210-230, August 1988.

“A Capital Asset Pricing Model with Time-Varying Covariances” (with T. Bollerslev and R.F. Engle), *Journal of Political Economy* 96, 116-131, February 1988.

Books

Solutions Manual and Supplementary Materials for Econometric Analysis of Cross Section and Panel Data, second edition. Cambridge, MA: MIT Press, 2011.

Econometric Analysis of Cross Section and Panel Data, second edition. Cambridge, MA: MIT Press, 2010.

Introductory Econometrics: A Modern Approach, fourth edition. Cincinnati, OH: South-Western College Publishing, 2009.

Introductory Econometrics: A Modern Approach, International Edition, Thomson, 2006.

Introductory Econometrics: A Modern Approach (Greek Translation), Thomson, 2006.

Introductory Econometrics: A Modern Approach, third edition. Cincinnati, OH: South-Western College Publishing, 2006.

Introductory Econometrics: A Modern Approach (Chinese Translation), Thomson, 2006.

Solutions Manual and Supplementary Materials for Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: MIT Press, 2003.

Introductory Econometrics: A Modern Approach, second edition. Cincinnati, OH: South-Western College Publishing, 2003.

Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: MIT Press, 2002.

Introductory Econometrics: A Modern Approach (Spanish Translation), Thomson, 2001.

Introductory Econometrics: A Modern Approach. Cincinnati, OH: South-Western College Publishing, 2000.

Book Chapters

“Teaching Undergraduate Econometrics,” in *International Handbook on Teaching and Learning Economics*, Gail Hoyt and KimMarie McGoldrick (eds.), 452-462. Cheltenham, United Kingdom: Edward Elgar, 2011

“Econometrics: Panel Data Methods,” in *Complex Systems in Finance and Econometrics*. Roberts Meyers (ed.), 215-237. Heidelberg, Germany: Springer, 2011.

“Stratified and Cluster Sampling,” in *The New Palgrave Dictionary of Economics*, second edition. Stephen Durlauf and Lawrence E. Blume (eds.). London: Palgrave Macmillan, 2008.

“Probabilistic Sampling,” in the *Handbook of Probability: Theory and Applications*. Tamás Rudas (ed.), 187-203. Los Angeles: Sage Publications, 2008.

“Instrumental Variables Estimation of the Average Treatment Effect in Correlated Random Coefficient Models,” in *Advances in Econometrics*, Volume 21 (Modeling and Evaluating Treatment Effects in Econometrics). Daniel Millimet, Jeffrey Smith, and Edward Vytlačil (eds.), 93-117. Amsterdam: Elsevier, 2008.

“Unobserved Heterogeneity and Estimation of Average Partial Effects,” in *Identification and Inference for Econometric Models: Essays in Honor of Thomas Rothenberg*. D.W.K. Andrews and J.H. Stock (eds.), 27-55. Cambridge: Cambridge University Press, 2005.

“Central Limit Theorems for Dependent Heterogeneous Processes with Trending Moments” (with H. White), in *New Perspectives in Econometric Theory: The Selected Works of Halbert White, Volume Two*, 464-481. Cheltenham, UK: Edward Elgar, 2004.

“Diagnostic Testing,” in *Companion to Theoretical Econometrics*. B.H. Baltagi (ed.), 180-200. Oxford: Blackwell, 2001.

“Asymptotic Properties of Some Specification Tests in Linear Models with Integrated Processes,” in *Cointegration, Causality, and Forecasting*. R.F. Engle and H. White (eds.), 366-384. Oxford: Oxford University Press, 1999.

“Quasi-Likelihood Methods for Count Data,” in *Handbook of Applied Econometrics*, Volume 2. M.H. Pesaran and P. Schmidt (eds.), 352-406. Oxford: Blackwell, 1997.

“Score Diagnostics for Linear Models Estimated by Two Stage Least Squares,” in *Advances in Econometrics and Quantitative Economics*. G.S. Maddala, P.C.B. Phillips, and T.N. Srinivasan (eds.), 66-87. Oxford: Blackwell, 1995.

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Appendix B

Documents Considered by Professor Jeffrey M. Wooldridge

Declaration of Roger G. Noll on Liability and Damages, dated April 3, 2013 (including Exhibits 1-16 and Appendices A-C).

Corrections to Declaration of Roger G. Noll on Liability and Damages, dated May 31, 2013 (including Exhibits 14, 15.1, 15.2, 16.1, 16.2).

Rebuttal Declaration of Roger G. Noll on Liability and Damages, November 25, 2013 (including Exhibits 1-6 and Appendices A-B).

Amended Expert Report of Robert H. Topel, dated August 19, 2013 2013 (including Exhibits 1-16 and Appendices A-D).

Corrections to Expert Report of Robert H. Topel Submitted July 19, 2013.

Amended Expert Report of Kevin M. Murphy, dated August 19, 2013 (including Exhibits 1-17 and Appendices A-D).

Corrections to Expert report of Kevin M Murphy Submitted July 19, 2013.